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Cyclomorphosis of Daphnia lumholtzi in Response to Spatial Heterogeneity in Lake Taylorville

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Eastern Illinois University

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CYCLOMORPHOSIS OF *DAPHNIA LUMHOLTZI*
IN RESPONSE TO SPATIAL HETEROGENEITY
IN LAKE TAYLORVILLE

by

KAREN K. SCHNAKE

THESIS

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2002

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ABSTRACT

Reservoir zonation occurs longitudinally as water enters from a stream into an impoundment. Inflow areas (or riverine zones) are typified by high flow rate and shallow depth whereas areas near the dam (lacustrine zones) characteristically have decreased flow and greater depth. In a typical reservoir, abiotic and biotic variables change somewhat predictably along a continuum from the riverine, through a transitional and into a lacustrine zone which can have a significant affect on the biota. *Daphnia lumholtzi*, a cladoceran which exhibits extreme cyclomorphosis, is an exotic species introduced to North America within the past twenty-five years. I examined the morphology of *D. lumholtzi* in three locations within Lake Taylorville anticipating to reflect unique riverine, transitional, and lacustrine features. Head, body, and tail lengths were determined from field collections made during 1993, 1994, 1999, and 2000.

As a result of a large watershed to surface area and high flow rates, the sites sampled did not vary in a manner predicted by reservoir limnological theory. Only riverine and transitional zones were found to exist in Lake Taylorville. Nonetheless, environmental variation that occurred among sample sites was found to significantly affect morphology of *D. lumholtzi*. Dissolved solids, Secchi depth, temperature, dissolved oxygen, chlorophyll a, conductivity, dissolved phosphate, and suspended phosphate either collectively or individually appear to influence spine formation. It is possible that phosphate acts as a limiting nutrient increasing the algal standing crop when available in later summer months when temperatures increase. Oxygen levels would subsequently increase as a result of elevated primary productivity while dissolved solids would decrease due to uptake by plankton. Reservoir clarity as indexed by Secchi depth

increases throughout the summer with decreased precipitation and sediment loading from the watershed. Increased water clarity may increase predator search efficiency causing lesser spined morphs to be consumed. It is likely that *D. lumholtzi* could be responding to a proximal cue such as temperature as well as light to reduce the effects of predation. Food availability may also be playing a role in spine formation by providing a resource to produce spines.

ACKNOWLEDGMENTS

I would like to thank Dr. Charles Pederson for serving as my adviser, providing his time and assistance with field collections, species identification, as well as guidance on this manuscript. I greatly appreciate all of his efforts that were extended throughout the duration of my time at Eastern Illinois University. I would also like to express my gratitude to Dr. Robert Fischer for his suggestions and comments on the manuscript as well as the study and for serving as a member of my graduate committee. I am also grateful to Dr. Kipp Kruse for his assistance on this paper as well as serving on my graduate committee. I would especially like to thank Dr. Scott Meiners for his help with the statistical analysis of my data.

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INTRODUCTION

Cyclomorphosis

According to Hutchinson (1967) the term cyclomorphosis was coined by Lauterborn (1904) to describe the 'seasonal polymorphism' of plankton. Black and Slobodkin (1987) defined cyclomorphosis more recently as 'temporal (seasonal or aseasonal), cyclic morphological changes that occur with in a planktonic population'. They, along with Jacobs (1961a), indicate that this phenomenon occurs commonly in taxa including dinoflagellates, rotifers, and Cladocera. Morphological changes may involve alteration of helmet size, helmet shape, carapace length and shape, tail spine length, and antennae length. These body structures may be involved simultaneously or independently (Yurista, 2000). Both proximate (environmental) and ultimate (evolutionary) explanations for induction of cyclomorphosis exist throughout the literature.

Proximal cues for cyclomorphosis were noted by the late 19th century when Zacharias (1894) noticed a temporal component to morphological variation in populations of cladocera such as *Daphnia.* Temperature and turbulence are two such proximal cues thought to induce helmet formation (Brooks, 1946, 1947; Hrbacek, 1959; Jacobs, 1961a,b, 1962, Hazelwood, 1966). Other cues such as light (Jacobs, 1962; Hazelwood, 1962, 1966) and soluble kairomones released by predators (Kruger & Dodson, 1981; Havel, 1985; Tollrian, 1990, 1994) also have been shown to cause cyclomorphosis. Since several species of *Daphnia* are known to be cyclomorphic, they have been well studied (Hutchinson, 1967). Jacobs (1961a) investigated several factors affecting cyclomorphic growth in *Daphnia mendotae* Birge, including temperature. Indicating embryogenic control independent of maternal morphological condition, he found a positive correlation between temperature and relative head length of neonates as well as post-natal head growth. Havel and Dodson (1985) found that turbulence and temperature induced cyclomorphosis in *Daphnia retrocurva* where invertebrate predators did not. Jacobs (1961a) along with De Beauchamp (1952) suggest that there is no limit to the numbers of possible environmental factors regulating cyclomorphosis.

Defense against predators (Dodson, 1974; Grant and Bayly, 1981; Pijanowska, 1990, and Swaffar and O'Brien, 1996) stability in swimming (Woltereck, 1909, 1913; Jacobs, 1987), buoyancy (Wessenberg-Lund, 1908; Jacobs, 1987), and adaptations for swimming (Hebert, 1978) all have been invoked as ultimate causes for cyclomorphosis. Spines may make a prey species harder to handle and consequently lead to increased likelihood of escape or rejection by a gape-limited predator (Zaret, 1980; Endler, 1986; Forbes, 1989; Swift, 1992), thus creating an argument for ultimate reasons for endurance of cyclomorphosis. Jacobs (1967) found crested *Daphnia* sp. less susceptible to guppy predation than uncrested individuals. Green's (1967) findings concur, stating that unhelmeted morphs are much more susceptible to fish predation than the helmeted morph. Pijanowska (1990) suggested that *Daphnia cucullata*'s elongated head and tailspine protected it against invertebrate predators. Although, Rawski (1997) found *Leptodora kindti* chose the spined *Daphnia lumholtzi* over the less spined *Daphnia pulex* and found *D. lumholtzi*'s spines failed to help protect it once captured.

Other arguments for ultimate causes were Woltereck's (1909, 1913) work on the stabilizing affect provided by spines during swimming. He observed backwards somersaulting after amputation of long antennules in *Bosmina longirostris* and a vertical passive sinking position *in Daphnia cucullata* after similar amputations. Hrbacek (1959) added that in *D. cucullata,* specimens with helmets are better able to resist displacement by current than are unhelmeted morphs. Lieder (1951) contradicted Woltereck and Hrbacek when *Bosmina coregoni* individuals lacking in one or two of their long antennules swam exactly as well as intact individuals. Although rejected by most (Brooks, 1946; Lieder, 1951), Wessenberg-Lund (1908) asserted that changes in spines helped to maintain buoyancy when water becomes less dense and less viscous during summer months.

Daphnia lumholtzi

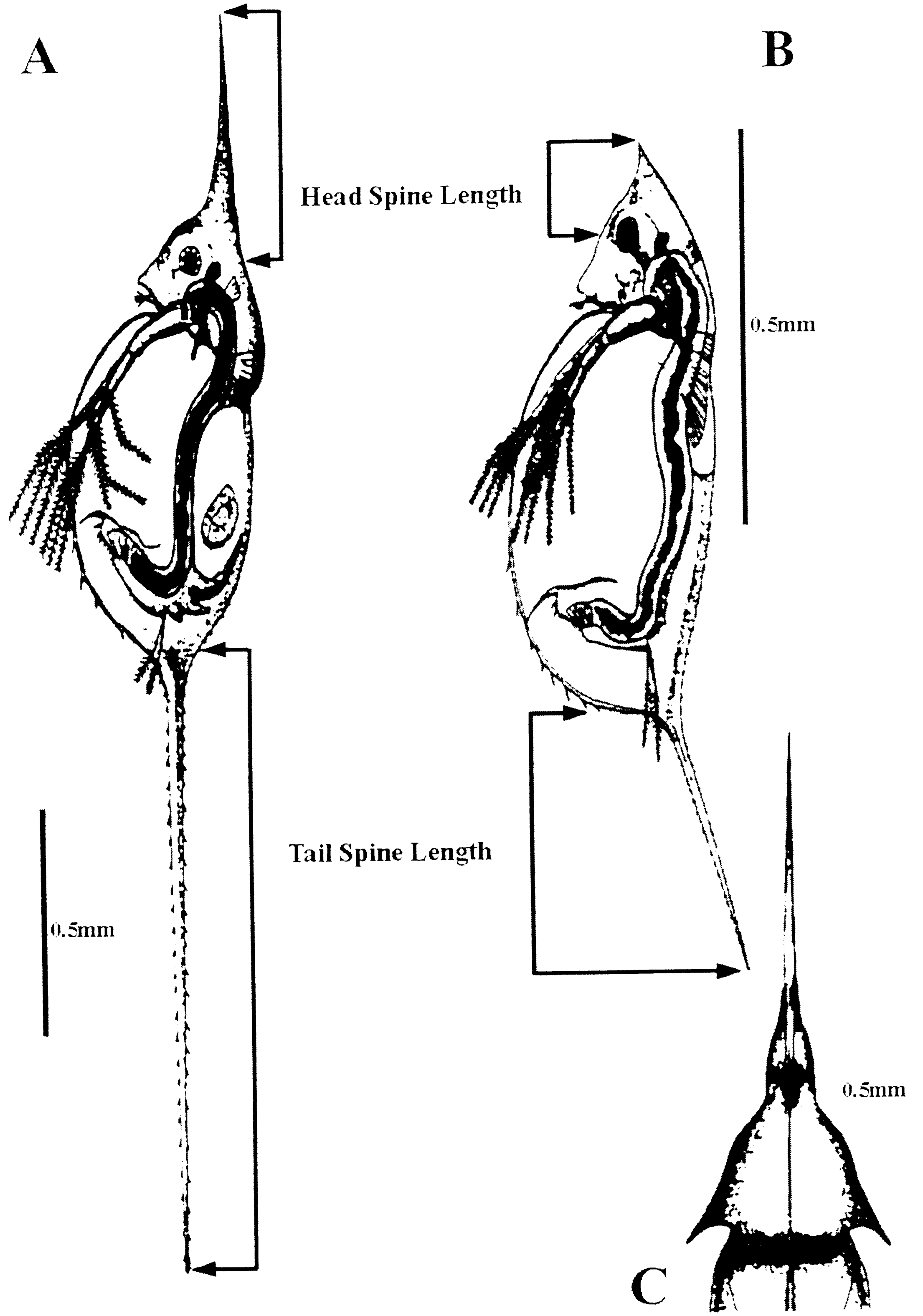
Daphnia lumholtzi is a cladoceran zooplankter with a natural distribution including southwestern Asia, Australia, and most of Africa (Benzie, 1988) where it can be found in habitats ranging from deep tectonic lakes to turbid temporary ponds. It was first reported in the United Stated in Fairfield Reservoir, Texas (31.7°N, 96°W) in 1991 by Sorensen and Sterner (1992). Initial introduction is believed to have occurred through stocking of fish imported from Africa. Fairfield Reservoir had such stockings of Tilapia (*Oreochromis aureus*) along with Nile perch *(Lates niloticus*) for a number of years prior to the confirmation of *D. lumholtzi* in the zooplankton (Ippolito, 1985; Sorensen and Sterner, 1992). *Daphnia lumholtzi* has since spread throughout central and southeastern United States (Havel and Hebert, 1993; Havel et al., 1995), including Illinois where Kolar et al. (1997) documented it in 1992 in plankton collected from Lake Springfield.

Daphnia lumholtzi was first described by G.O. Sars in 1885 to have a 'distinct dorsal impression' or head spine and noted the prominence of the fornices. Sorensen and Sterner (1992) went on to describe *D. lumholtzi* as having 'a pronounced helmet which can reach lengths nearly equal to the body', a tail spine which can exceed the body length, 'pronounced fornices which increase with body width', and spines existing on the ventral margin of the carapace. Havel and Hebert (1993) distinguished *D. lumholtzi* by stating that the helmet is larger than those produced by native species (with the exception of *Daphnia ambigua*), the length of the tail spine is longer than any other Daphnid, its fornices are distinctively pointed, and approximately 10 spines exist on the ventral carapace margin (Fig. 1). Total length including spines can exceed 5mm which is greater than the length of native North American *Daphnia* (Work and Gophen, 1995). The extreme morphology exhibited by *D. lumholtzi* enables this species to demonstrate profound cases of cyclomorphosis, with length of helmet and tail spine showing marked variation both seasonally (Sorensen and Sterner, 1992) and within regions of a single lake (Green, 1967).

Reservoir Characteristics

Lotic ecosystems represented by streams and rivers are characterized by longitudinal gradients while lentic ecosystems represented by "lake-like" environments are identified by their vertical gradients. Since reservoirs typically are constructed by impounding streams or rivers, they form hybridized river-lake systems often with pronounced vertical stratification and longitudinal zonation of physical, chemical, and biological factors (Thorton et al., 1990). Because reservoirs typically have higher watershed to surface area ratios than do natural lakes, standard limnology may not always be applicable for understanding the ecology of reservoirs (Fig. 2). Greater flow, higher suspended solids concentration and more rapid nutrient enrichment are outcomes of these differences (Kalff, 2002; Thorton et al., 1990; Phipps, 1994).

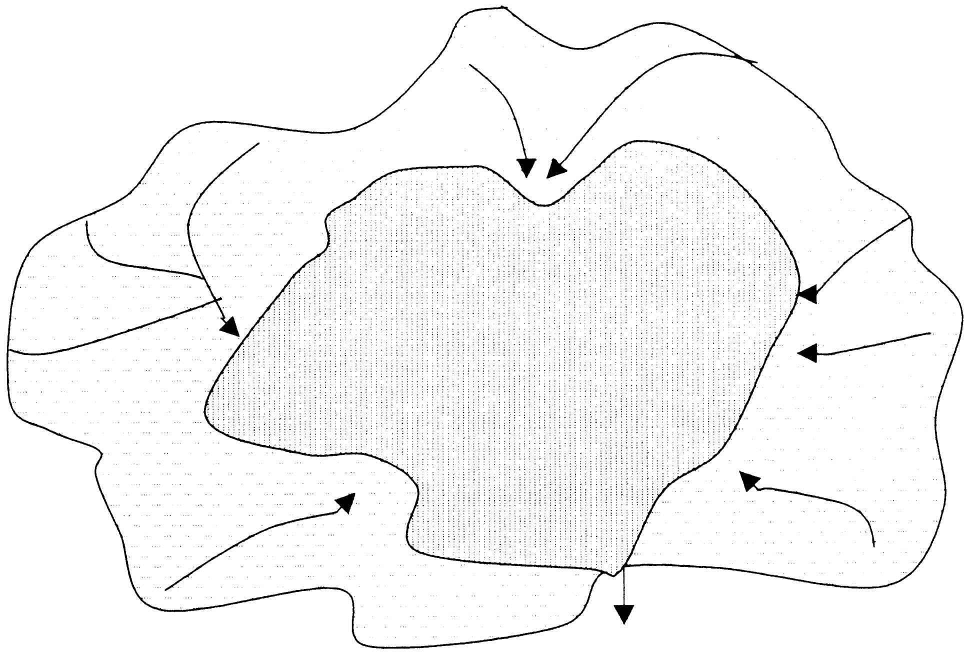
Figure 1. Morphologic features advantageous for identification of *Daphnia lumholtzi* with reference to measurements used for calculating head, body, and tail size. A and B- female lateral; C-female dorsal (modified from Havel and Hebert, 1993).



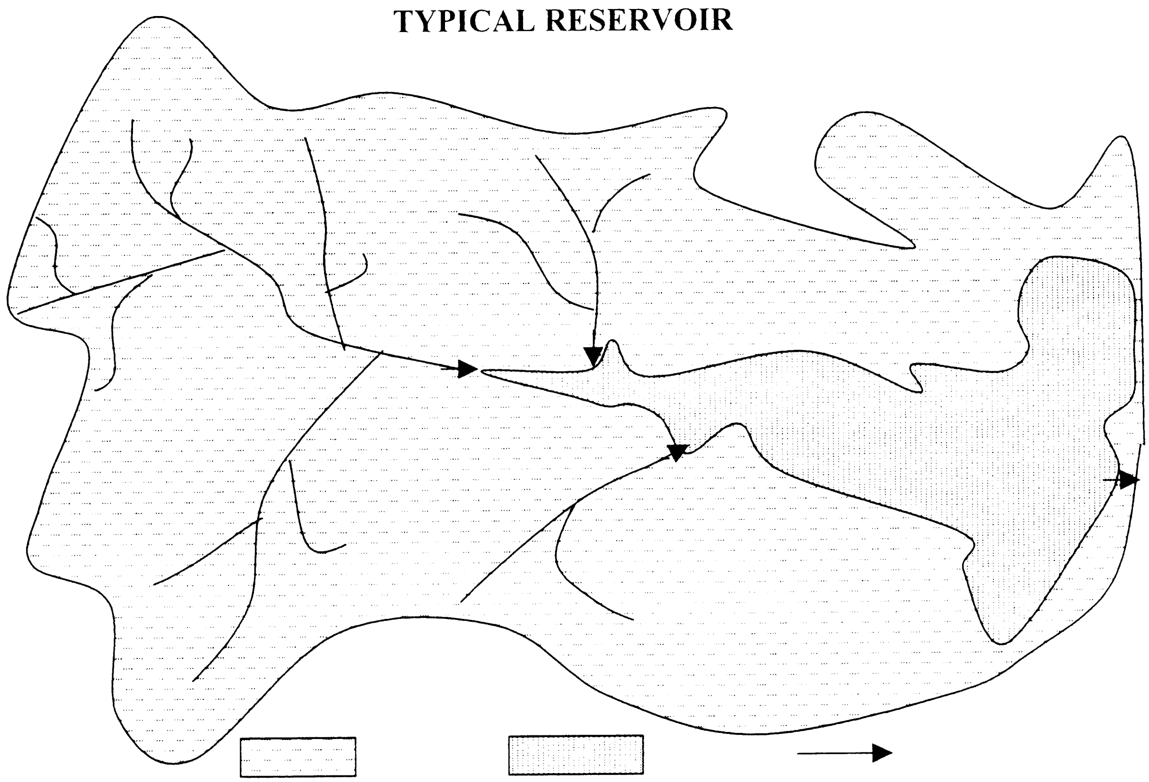
A
B
Head Spine Length
0.5mm
Tail Spine Length
0.5mm
0.5mm
C

Figure 2. The relationship between surface area and drainage area in reservoirs and natural lakes (modified from Phipps, 1994).

TYPICAL LAKE



TYPICAL RESERVOIR



Drainage area Lake/Reservoir Stream

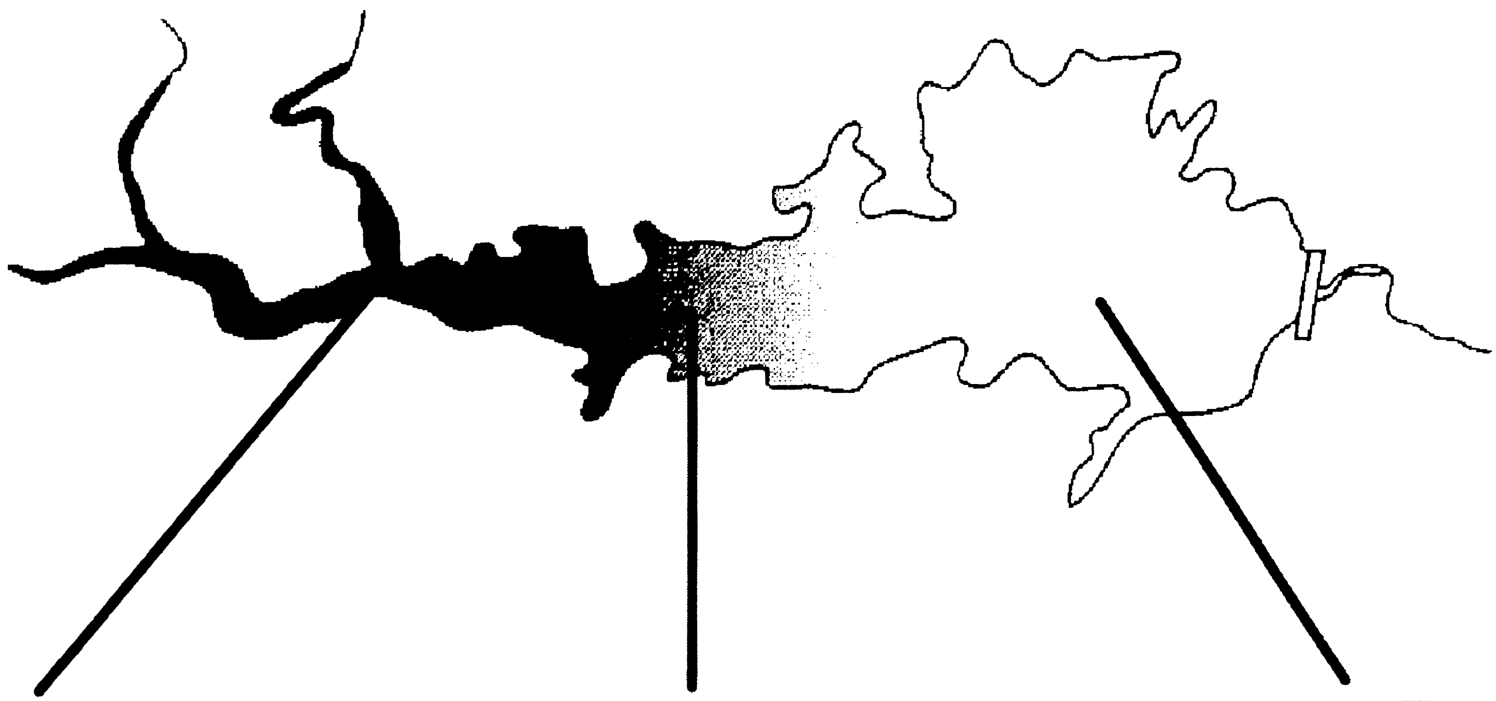
According to Kimmel and Groeger (1984), longitudinal gradients in environmental factors occur along a continuum in reservoirs resulting in three zones referred to as the riverine, transitional, and lacustrine zone (Fig. 3). The riverine zone (river- or stream-like) is typified by shallow depth and a high flow rate, resulting in elevated concentrations of suspended solids and nutrients but low productivity due to light limitation. The transitional zone is characterized by decreased flow and increased sedimentation rates thus leading to increased light availability. High nutrient concentrations combined with increased light penetration often make the transitional zone the most productive area of a reservoir. The lacustrine zone (lake-like) has decreased flow rates and greater depth often resulting in thermal stratification, decreased suspended solids, greater light penetration, but lower productivity due to lower nutrient availability (see also Thorton et al., 1990).

Fluctuating flow rates can alter the boundaries of these zones. Decreased flow shortens the riverine zone by increasing sedimentation rates leading to enhanced water clarity resulting in a shift of high productivity toward the inflow. Decreased flow also allows the concurrent expansion of the lacustrine zone. Increased flow reverses these effects and potentially could eliminate the lacustrine zone completely (Fig. 4).

Lake Taylorville

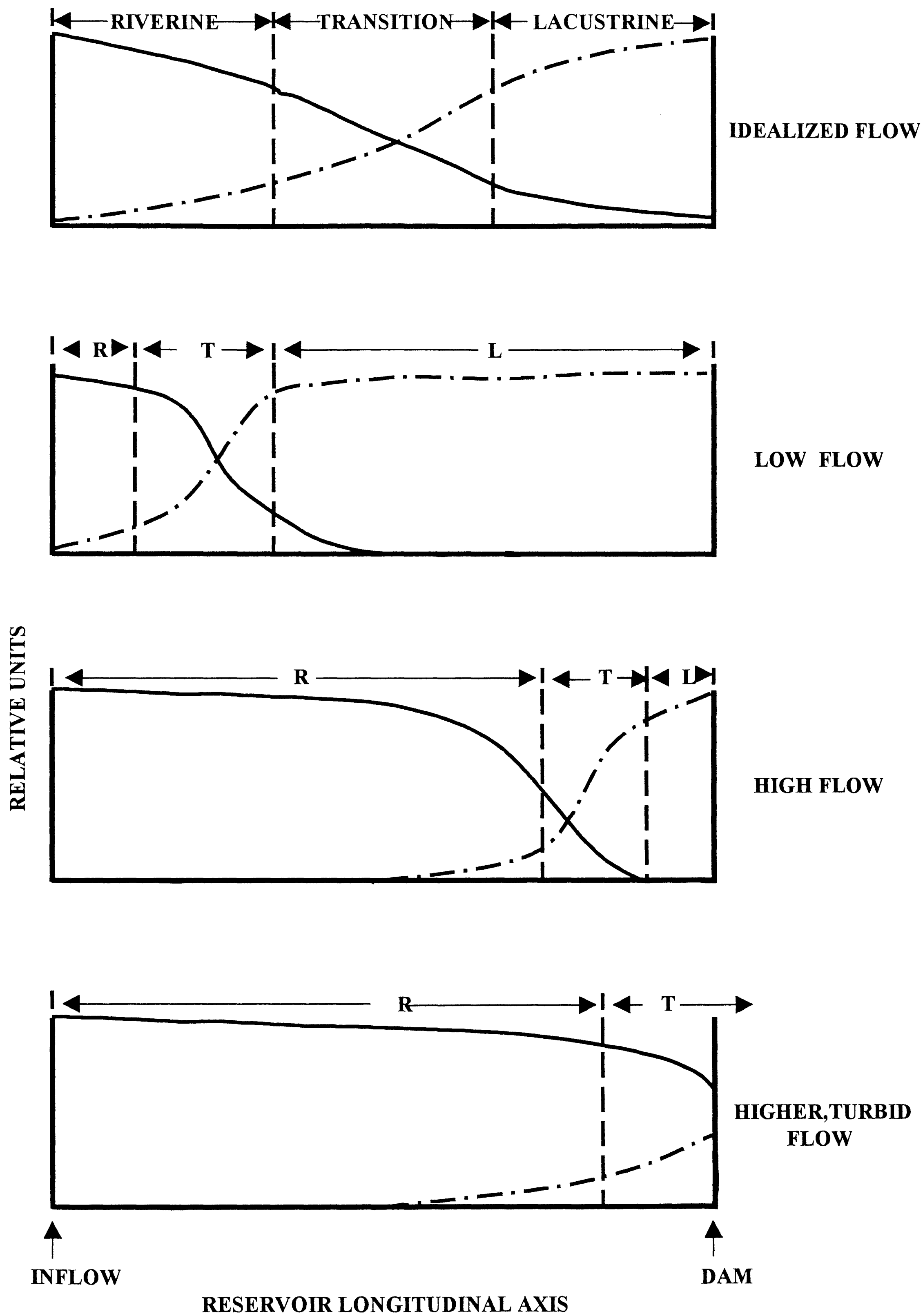
Located in Christian County, Lake Taylorville is an impoundment of the South Fork Sangamon River. It began impounding water from a primarily agricultural watershed of approximately 33,994 hectares in 1962. The reservoir has a surface area of

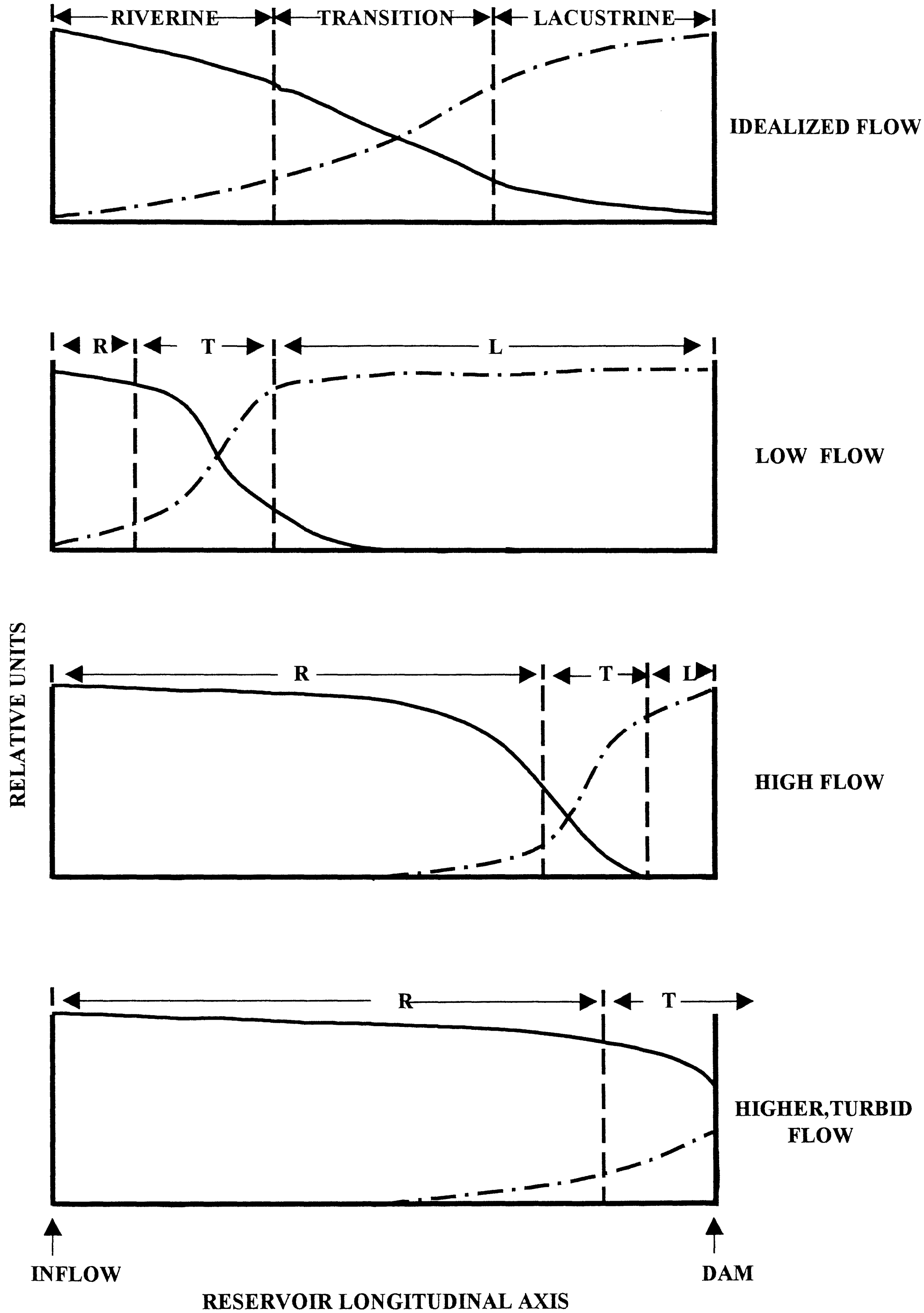
Figure 3. Longitudinal zonation of environmental factors in a reservoir (modified from Kimmel and Groeger, 1984).



RIVERINE ZONE	**TRANSITIONAL ZONE**	**LACUSTRINE ZONE**
-NARROW, CHANNELIZED BASIN	-BROADER, DEEPER BASIN	-BROAD, DEEP, LAKE-LIKE BASIN
-RELATIVELLY HIGH FLOW	-REDUCED FLOW	-LITTLE FLOW
-HIGH SUSP. SOLIDS, TURBID LOW LIGHT AVAILABILITY	-REDUCED SUSP. SOLIDS, LESS TURBID, LIGHT AVAILABILITY INCREASED	-REL. CLEAR, LIGHT MORE AVAILABLE
-NUTRIENT SUPPLY BY ADVECTION RELATIVELY HIGH NUTRIENTS	-ADVECTIVE NUTRIENT SUPPLY REDUCED	-NUTRIENT SUPPLY BY INTERNAL RECYCLING, REL. LOW NUTRIENTS
-ALGAL CELL LOSES PRIMARILY BY SEDIMENTATION	-ALGAL CELL LOSSES BY SEDIMENTATTION AND GRAZING	-ALGAL CELL LOSSES PRIMARILY AUTOCHTHONOUS

Figure 4. Longitudinal zonation of environmental factors in a reservoir varying due to a change in flow. Solid lines represent riverine conditions while dashed lines represent lacustrine conditions (modified from Thorton et al., 1990).


RIVERINE
TRANSITION
LACUSTRINE
IDEALIZED FLOW
R
T
L
LOW FLOW
RELATIVE UNITS
R
T
L
HIGH FLOW
R
T
HIGHER,TURBID
FLOW
INFLOW
DAM
RESERVOIR LONGITUDINAL AXIS


RIVERINE
TRANSITION
LACUSTRINE
IDEALIZED FLOW
R
T
L
LOW FLOW
RELATIVE UNITS
R
T
L
HIGH FLOW
R
T
HIGHER,TURBID FLOW
INFLOW
DAM
RESERVOIR LONGITUDINAL AXIS

445 hectares creating a high flow system due to a 76: 1 watershed to surface area ratio. As a result of its agricultural surroundings, sedimentation and nutrient enrichment from runoff has led to eutrophication, water quality degradation, and loss of reservoir capacity from rapid accumulation of sediments. A restoration program created a series of floodplain wetlands, riverine wetlands, holding ponds and sediment basins on tributaries in effort to abate sedimentation and nutrient loading in 1994.

Objectives

Few studies have looked at a wide range of abiotic factors that could affect cyclomorphosis with in a lake or reservoir. Brooks (1946, 1947) and Hebert and Crease (1980) infer that field populations are genetically homogeneous because cyclomorphosis typically occurs across successive, parthenogenetically produced generations. Consequently, morphological differences which may be observed *in situ* likely result from proximal cues. Reservoirs are heterogeneous with physically and chemically distinct zones (Kimmel and Groeger 1984; Thorton et al., 1990) which may induce morphological variation in cyclomorphic species. It is the purpose of this study to investigate whether the intensity of cyclomorphosis varies along a reservoir gradient and to attempt to determine which environmental variables act alone or in concert to serve as proximate cues. Since *D. lumholtzi* exhibits such extreme cyclomorphosis (Sorensen and Sterner, 1992) and Lake Taylorville is a reservoir, we chose to examine *D. lumholtzi* in Lake Taylorville for this study to investigate various abiotic factors that could affect cyclomorphosis.

METHODS

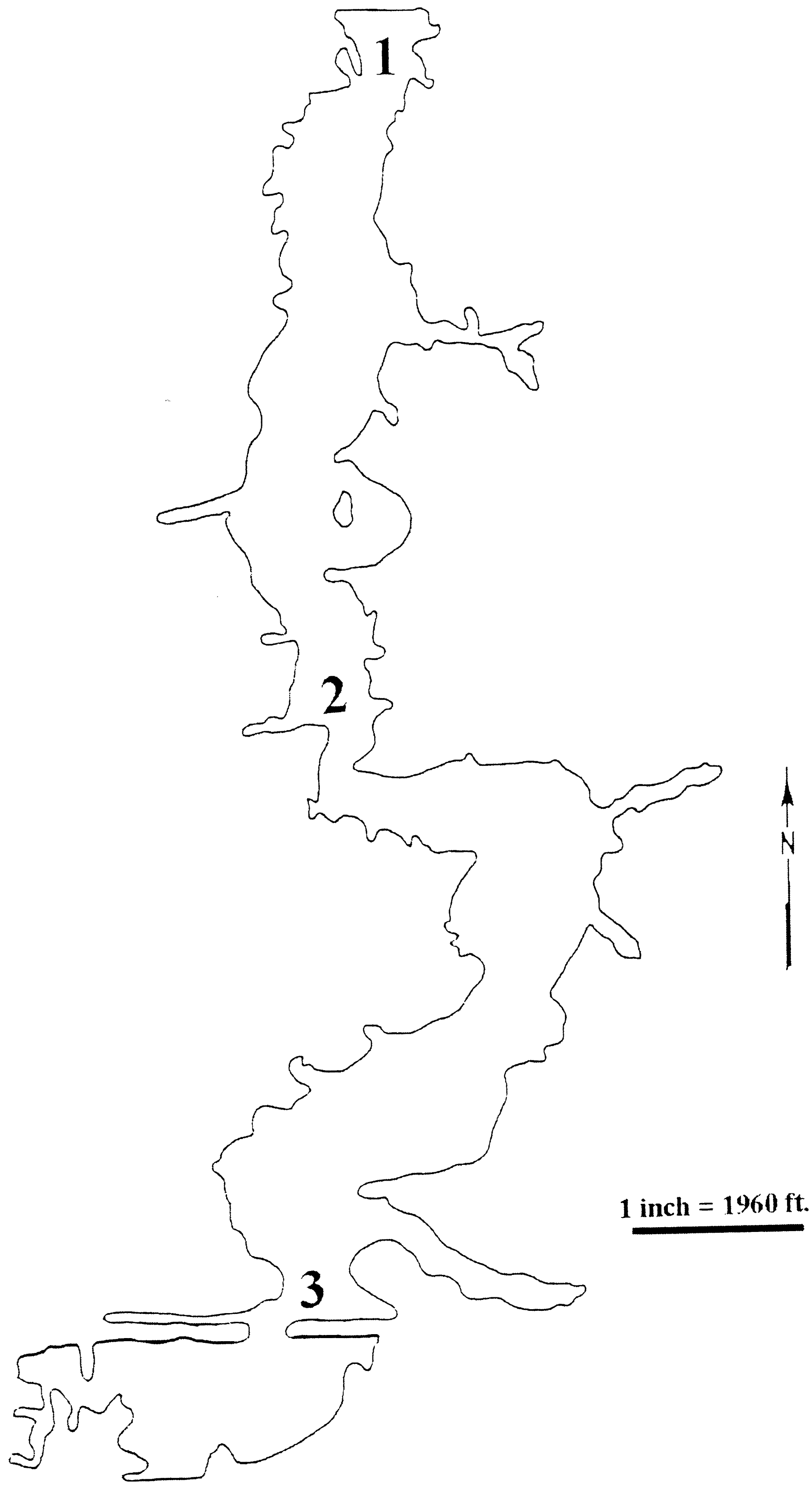
Sampling Procedures

Zooplankton were collected bi-monthly during summer months and monthly the remainder of the year in 1993, 1994, 1999, and 2000 at three sites in Lake Taylorville (Fig. 5) during daylight hours. Sites were chosen to provide a depth gradient along the length of the reservoir and to represent three distinct reservoir zones (riverine, transitional, and lacustrine). A single vertical tow was taken at each site with an 80-µm mesh sized zooplankton net from bottom to surface. Samples were immediately preserved in 4% formalin solution.

In the laboratory, up to 50 *D. lumholtzi* were measured with an ocular micrometer at 400x. The first specimens encountered per sample were measured to incorporate all body sizes in our analysis to prevent bias. Head, body, and tail measurements were referenced from the center of the eye and from the base of the tail spine (Fig. 1). Total length was obtained by combining all three measurements. Zooplankton identification and measurements were performed according to Pennak (1953) and Sorensen and Sterner (1992).

Surface physical and chemical variables were determined at all three sites fore each sample period. Methodology of collection and evaluation of these abiotic variables can be referenced to Phipps (1994) for the 1993 data, Hall (unpublished data) for the 1994 data, and Druffel (unpublished data) for the 1999 and 2000 data. Analyses for 1993 and 1994 abiotic data followed procedures according to standard methods (APHA 1985) while 1999 and 2000 procedures were from standard methods (APHA 1995).

Figure 5. Map of Lake Taylorville showing approximate locations of sample collection sites used in this study. Marker 1 is the location of the Dam site (lacustrine zone), marker 2 is the location of the Midlake site (transitional zone), and marker 3 is the location of the Inflow site (riverine zone) (modified from IEPA, 1980).


1
2
3
N
1 inch = 1960 ft.

Statistical Analysis

Two-way analysis of variance (ANOVA) with interaction was used to determine significant differences between mean head, body, and tail ratios with sites and years as independent variables. The ratios were made suitable for parametric analyses by performing arcsine transformations to normalize the data (Sokal and Rohlf, 1981).

Principal components analysis (PCA) was performed on the correlation matrix of date and site specific data of dissolved and suspended solids, Secchi depth, pH, temperature, dissolved oxygen, alkalinity, total oxidized nitrogen, chlorophyll a, conductivity, dissolved and suspended phosphorus. PCA forms new orthogonal axes from the original matrix of variables. These axes represent the suite of variables that correlated (loaded) highly with that axis. Pearson correlation coefficients were calculated to determine which of the environmental variables loaded significantly on each of the axes (Zar, 199) and to correlate the environmental PCA scores with mean body proportions (transformed by arcsin). SPSS for Windows 10.1 (Morgan and Griego, 1998) was used to perform all statistical analyses.

RESULTS

Daphnia lumholtzi was a component of the zooplankton community in Lake Taylorville in 1993, 1994, 1999, and 2000. My earliest seasonal observation of *D. lumholtzi* occurred in 1993 when it was noted in samples collected on 25 May. Peak abundances typically were observed in middle to late summer, although the species persisted into December during 1994 (see Appendix A). Overall, head and tail spines comprised an average (n = 1484) of 22.20 and 40.49 percent of total length, respectively. However, morphology varied considerably among sites (Dam, Midlake, and Inflow) and over time (1993, 1994, 1999, and 2000) (Figures 6-8.). Two factor analysis of variance revealed significant main effects of site and year for head spine, body, and tail spine proportions of total length. Site by year interaction was significant only for head spine and tail spine proportions (Table 1). Significant interaction of the main effect variables suggests that morphology of *D. lumholtzi* does not vary in a fashion predictable only on the basis of position within the reservoir. Rather, the observed cyclomorphosis may be in response to fluctuation of the local environment. As a result, I decided to use a multivariate approach to characterize the reservoir environment on the basis of selected physical, chemical, and biological variables for each sampling event (site x date combination).

Environmental variables were not included in Principal Components Analysis (PCA) for sampling dates on which *D. lumholtzi* was not observed as a member of the zooplankton community (Appendix B). PCA extracted four axes which explain a total of 67.52% of the variation within the environmental data (Table 2). Each axis from the PCA arranges individual sampling events in accordance to relationship with each other. Samples grouped closely together are more related than those that are further away.

Figure 6. Mean head length (± 1 SD) as a proportion of total length of *Daphnia lumholtzi* in Lake Taylorville.

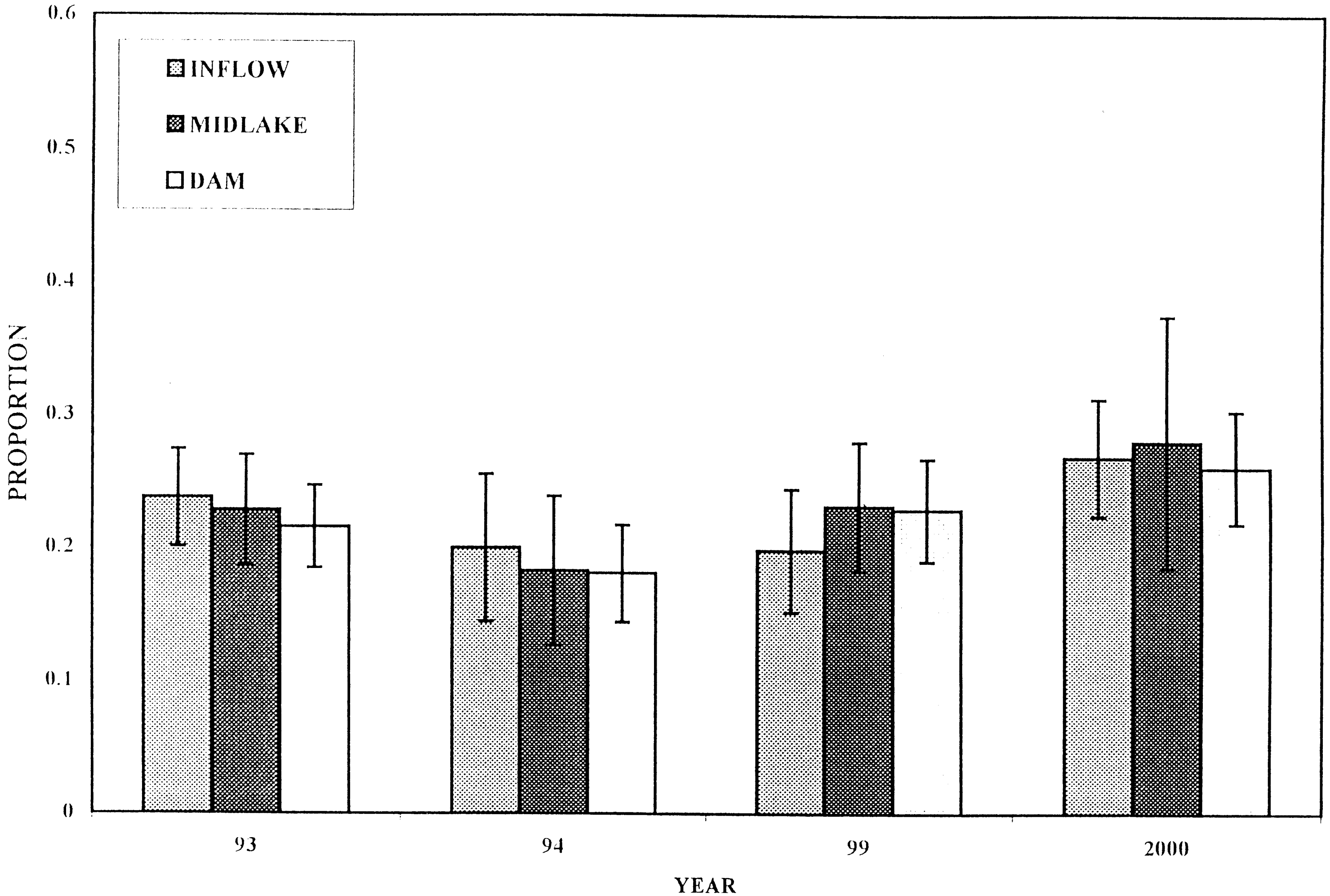
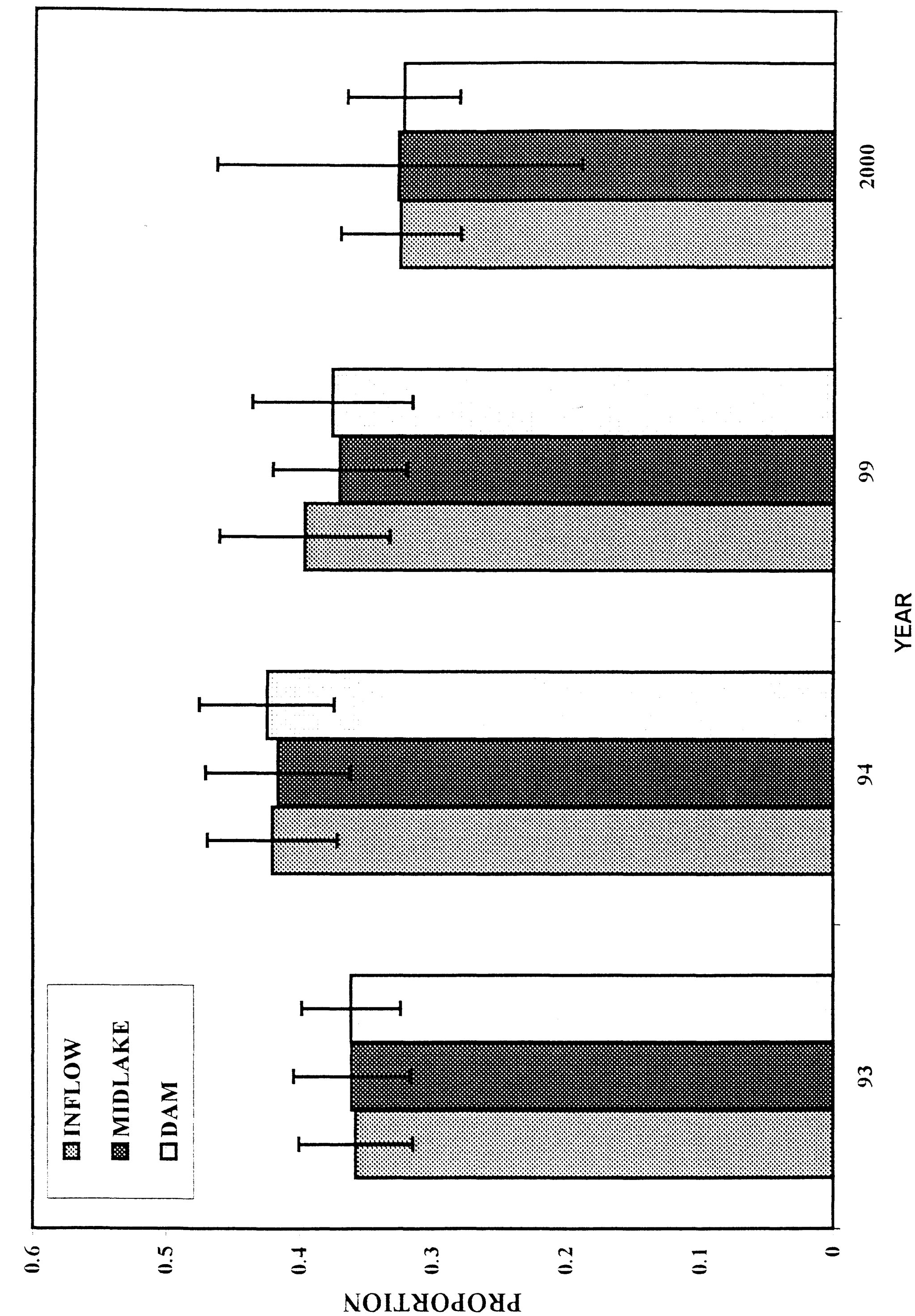
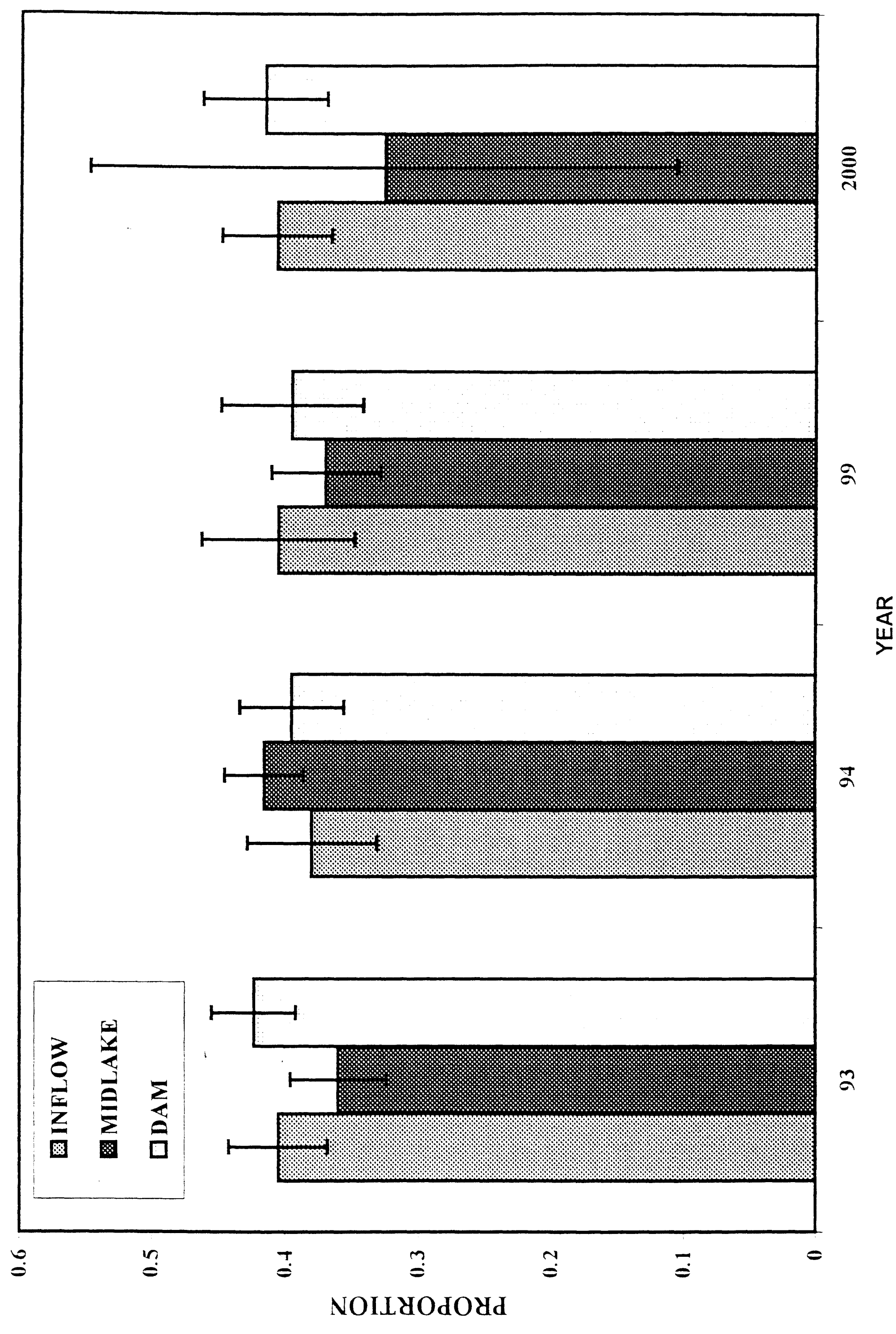

INFLOW
MIDLAKE
DAM
0.6
0.5
0.4
0.3
0.2
0.1
0
PROPORTION
93
94
99
2000
YEAR

Figure 7. Mean body length (± 1 SD) as a proportion of total length of *Daphnia lumholtzi* in Lake Taylorville.



INFLOW
MIDLAKE
DAM
PROPORTION
0.6
0.5
0.4
0.3
0.2
0.1
0
93
94
99
2000
YEAR

Figure 8. Mean tail length (±1 SD) as a proportion of total length of *Daphnia lumholtzi* in Lake Taylorville.



INFLOW
MIDLAKE
DAM
PROPORTION
0
0.1
0.2
0.3
0.4
0.5
0.6
YEAR
93
94
99
2000

Table 1. ANOVA results from proportions transformed by arcsine (* = p<0.05).

Source	Head proportion		Body proportion		Tail proportion	
	df	F	df	F	df	F
Year	3	198.87*	3	223.72*	3	16.29*
Site	2	4.42*	2	3.41*	2	3.77*
Year * Site	6	8.64*	6	2.02	6	2.94*
Error	1472		1472		1472	

Table 2. Principal component analysis axes explaining variation among sampling events within a suite of environmental variables.

Axis	% of Variance	Cumulative %
1	24.06	24.06
2	17.69	41.75
3	13.63	55.38
4	12.14	67.52

PCA scores were then correlated to environmental variables to determine which variables loaded significantly ($p < 0.05$) onto specific axes. The first axis, comprised of dissolved solids, suspended solids, Secchi depth, pH, temperature, dissolved oxygen, alkalinity, total oxidized nitrates, conductivity, and dissolved phosphorus, explains 24.06 % of the environmental variation which occurred among sampling events. The second axis consisted of dissolved solids, temperature, chlorophyll a, dissolved and suspended phosphorus and contributed 17.69 % to the total variation. The third axis was made up of dissolved solids, Secchi depth, dissolved oxygen, chlorophyll a, and dissolved and suspended phosphorus representing 13.63 % of the environmental variation. Lastly, the fourth axis correlated significantly with Secchi depth, temperature, dissolved oxygen, and conductivity where 12.14 % of the variation existed.

Pearson correlations were used to determine which of these axes were significant in relation to *D. lumholtzi* morphology. Only the second and fourth axes correlated significantly ($p < 0.05$) with *D. lumholtzi* morphology. Consequently, the first and third axes were dropped from the remaining analyses (Table 3). Head and tail spine proportions were positively correlated to the second and fourth PCA axes while the body proportion was negatively correlated. As these axes increased in value, the spines in *Daphnia lumholtzi* proportionally became larger while the body proportion was reduced.

The correlation between the PCA axes and *D. lumholtzi* morphology suggests possible environmental influence on spine formation. Physical and chemical variables that significantly correlated with these axes either collectively or individually

Table 3. Correlations of arcsine transformed body proportions with the first four principa component axes. Significance of Pearson correlation coefficients (r), *= $p < 0.05$, $n = 54$.

Proportion	PCA 1		PCA 2		PCA 3		PCA 4	
	r	p	r	p	r	p	r	p
Head	0.04	0.77	0.59*	0.00	-0.08	0.55	0.25	0.07
Body	-0.07	0.63	-0.60*	0.00	0.12	0.40	-0.31*	0.03
Tail	0.06	0.68	0.32*	0.02	-0.14	0.33	0.29*	0.03

contribute to *D. lumholtzi* morphology. Due to their correlation with the second PCA axis, the following could be affecting morphology: chlorophyll a, suspended phosphate, temperature, dissolved phosphate, and dissolved solids. Conductivity, Secchi depth, temperature, and dissolved oxygen due to their positive correlations with the fourth axis (Table 4) could also influence cyclomorphosis significantly.

DISCUSSION

Daphnia lumholtzi Morphology

A normally functioning reservoir typically has characteristics that distinguish each longitudinal zone (riverine, transitional, and lacustrine). However, the abiotic environment with in Lake Taylorville is highly variable and does not fit expectations of distinct zones as described in Thorton et al. (1990). Phipps (1994) found no significant differences between sites for nutrients, chlorophyll a, conductivity, total suspended solids, pH or dissolved oxygen. Total solids, total dissolved solids, temperature, and Secchi depth were found to differ significantly between sites after running an ANOVA. Lake Taylorville was interpreted by Phipps (1994) as a high flow reservoir, suggesting that the lacustrine zone was absent causing the system to act more as a river.

If the zones were more distinct and stable, then I might expect *D. lumholtzi* morphology to vary simply as a function of sample location. Individual *D. lumholtzi* may alter spine proportion which can increase or decrease with subsequent molts in response to the surrounding environment. Over-crowding, food availability, and temperature seemed to affect spine length (personal observations). The ability of a species to change morphological properties allows a prey species such as *D. lumholtzi* to become harder to handle and consequently lead to an increased chance of escape or rejection by a gape-limited predator (Zaret, 1980, Endler, 1986, Forbes, 1989, and Swift, 1992). *Daphnia lumholtzi* possessing longer head and tail spines could remain in higher abundance collectively causing the population to appear to be more spiny due to selective removal of lesser spined morphs (Kolar et al., 1997, Zaret 1980). Significant morphological differences occurring between sites and years indicate that *D. lumholtzi* morphology was highly variable in Lake Taylorville. While I am not able to assess the effect of existing

Daphnia lumholtzi Morphology

A normally functioning reservoir typically has characteristics that distinguish each longitudinal zone (riverine, transitional, and lacustrine). However, the abiotic environment with in Lake Taylorville is highly variable and does not fit expectations of distinct zones as described in Thorton et al. (1990). Phipps (1994) found no significant differences between sites for nutrients, chlorophyll a, conductivity, total suspended solids, pH or dissolved oxygen. Total solids, total dissolved solids, temperature, and Secchi depth were found to differ significantly between sites after running an ANOVA. Lake Taylorville was interpreted by Phipps (1994) as a high flow reservoir, suggesting that the lacustrine zone was absent causing the system to act more as a river.

If the zones were more distinct and stable, then I might expect *D. lumholtzi* morphology to vary simply as a function of sample location. Individual *D. lumholtzi* may alter spine proportion which can increase or decrease with subsequent molts in response to the surrounding environment. Over-crowding, food availability, and temperature seemed to affect spine length (personal observations). The ability of a species to change morphological properties allows a prey species such as *D. lumholtzi* to become harder to handle and consequently lead to an increased chance of escape or rejection by a gape-limited predator (Zaret, 1980, Endler, 1986, Forbes, 1989, and Swift, 1992). *Daphnia lumholtzi* possessing longer head and tail spines could remain in higher abundance collectively causing the population to appear to be more spiny due to selective removal of lesser spined morphs (Kolar et al., 1997, Zaret 1980). Significant morphological differences occurring between sites and years indicate that *D. lumholtzi* morphology was highly variable in Lake Taylorville. While I am not able to assess the effect of existing predators on *D. lumholtzi* morphology, I can address potential influence of the environment which could explain why morphologic differences were found.

The Abiotic and Biotic Environment

Principal components analysis (PCA) enables characterization of the variable nature of the sample sites in Lake Taylorville. This ordination procedure which condenses a large array of variables into a more manageable set of derived variables. Relationships existing within the data are summarized in the axes created by PCA.

The second PCA axis may generally describe a combined measure of primary productivity in Lake Taylorville. The positive correlation between this axis and chlorophyll a, temperature, dissolved and particulate phosphorus, and negative correlation of the axis with total dissolved solids may serve as indices of productivity. Summer months generally bring about higher temperatures and algal standing crop (as chlorophyll a) was elevated in Lake Taylorville at these times. The algal standing crop rose during periods when phosphate was abundant resulting in increased uptake of other dissolved solids. According to Hutchinson (1961), a limiting nutrient is that nutrient that is in shortest supply relative to need. Algal growth rate is affected by the availability of some limiting factor such as light and increases until another factor such as nutrients or temperature becomes more limiting (Reynolds, 1984; Thorton et al., 1990). Phipps (1994) found Lake Taylorville water spiked with nitrates did not show any significant difference in algal growth compared to water that was unspiked, but significant differences did occur when water was spiked with phosphate describing the positive correlations of phosphate measurements and chlorophyll a in this study. The negative correlation of dissolved solids could be a result of uptake by plankton (Thorton et al., 1990).

The fourth PCA axis may be more of a general summation of the overall physical environment given the positive correlations with Secchi depth, temperature, dissolved oxygen, and conductivity. Decreased precipitation during summer may cause expansion of the lacustrine zone. At these times, reservoir clarity as measured by Secchi depth tends to increase. Enhanced water clarity would be advantageous for predators by increasing their search efficiency and thereby removing those daphnids that are less spiny. Also higher algal standing crop seen in later summer months may result in higher dissolved oxygen. The correlation of the fourth axis from PCA with conductivity is anomalous.

Daphnia lumholtzi Morphology and the Environment

Correlation of *D. lumholtzi* morphology with PCA scores allows evaluation, *in situ*, of the potential effects of the abiotic and biotic environment on cyclomorphosis. *Daphnia lumholtzi* morphology was correlated significantly to both the second and fourth PCA axes. As levels of these axes increase, head and tail spines become more prevalent while body proportions decrease. Development of cyclomorphic features appears to be in response to some aggregate or individual measure of environmental variability within Lake Taylorville.

Sorensen and Sterner (1992) suggest that several factors could influence cyclomorphosis such as temperature, food limitation, and predation by both invertebrate and vertebrate predators. They noted that the degree of spine formation varies over time. Jacobs (1961) found a positive relationship between head growth rates and temperature in

Daphnia geleata mendotae. Temperature also has been found to induce a strong cyclomorphic response up to a particular threshold in *D. lumholtzi* (Yurista, 2000) and in *D. pulex* (Havel, 1985). Havel and Dodson (1985) also found temperature to induce cyclomorphosis in *Daphnia retrocurva*. My study concurs with the previous studies in finding a positive relationship with temperature and both of the PCA axes which correlated *D. lumholtzi* morphology.

The affect of temperature on cyclomorphosis can be explained from several different perspectives. Warmer temperatures cause invertebrate predators such as *Chaoborus* to feed at higher rates (Feodorenko, 1975). Since midges consume "typical" *D. pulex* more efficiently than spined *D. pulex* (Havel and Dodson, 1984) the percent of spined morph increases due to selective predation pressures. Havel (1985) provided another perspective by suggesting that there might be higher levels of kairomones released by *Chaoborus* at warmer temperatures. Havel also speculated that developing *D. pulex* might react more to concentrations of such kairomones at higher temperatures.

Benzie (1991) altered yeast concentrations in field enclosures to measure cyclomorphosis. Spines were found to be smaller in *Daphnia carinata* when food availability was reduced regardless of predator presence or absence. I found a positive relationship with chlorophyll a, representing a measure of standing crop of the phytoplankton, in the second axis supporting Benzie's work with respect to food levels affecting cyclomorphosis. Benzie also thought oxygen stress had a minimal affect on spine formation. The work of Grant and Bayly (1981) concur that varied dissolved oxygen levels had no effect on crest development in *D. carianata*. The positive relationship of dissolved oxygen to the fourth axis in my study provides conflicting results with respect to the morphology found in *D. lumholtzi,* although increased dissolved oxygen could be a result of increased phytoplankton levels. The relationship is not clear.

A genetic component could possibly be the underlying factor affecting the degree of cyclomorphism in Lake Taylorville. Havel (1985) suggests that through clonal succession in response to seasonal changes, relative frequencies of genotypes change. Lynch (1983) supports this theory with the observation of several clonal groups of *D. pulex* coexisting in a pond, implying that their relative frequencies changed over time. Brooks (1946, 1947) and Hebert and Crease (1980) argue that cyclomorphosis occurs in genetically homogeneous populations since daphnids reproduce parthenogenetically. Subsequent studies where samples would be taken at distinct sites across reservoir zones and tested for genetic homogeneity or plasticity in *D. lumholtzi* would help to alleviate this uncertainty relative to Lake Taylorville.

Research that incorporates controlled variations of environmental variables with the presence and absence of vertebrate as well as invertebrate predators would help to clarify what mechanisms are affecting cyclomorphosis. Experiments where environmental variables were tested individually as well as in concert on spine formation would aid in teasing apart the many questions that surround cyclomorphosis. *Daphnia lumholtzi* acquired from Lake Taylorville and reared in laboratory conditions where biotic and abiotic levels are similar should be tested against varying concentrations of such physical conditions. Cyclomorphic responses could be monitored by using the environmental variables that were found significantly correlated to PCA axis two and four alone as well as collectively. While my study provides general descriptions of environmental affects on cyclomorphosis in *D. lumholtzi* from Lake Taylorville, conducting such experiments would enable a more direct description of what can influence cyclomorphosis.

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APPENDICES

Appendix A. *Daphnia lumholtzi* morphometric measurements (mm). I (Inflow), M (Midlake), D (Dam).

1993					1994					1999					2000				
Date	Sit	Head	Body	Tail	Date	Sit	Head	Body	Tail	Date	Site	Head	Body	Tail	Date	Site	Head	Body	Tail
930525	M	0.468	0.78	0.806	940701	I	0.754	1.3	1.456	990923	I	0.55	1.025	1.35	00062	M	0.475	0.525	0.65
930525	D	0.858	1.794	1.846	940701	D	0.598	0.962	1.274	990923	I	0.225	0.45	0.4	00062	M	0.625	0.525	0.775
930525	D	0.286	0.52	0.546	940701	D	0.312	0.598	0.494	990923	I	0.6	1.075	1.15	00062	M	0.5	0.575	0.725
930614	M	0.338	0.494	0.624	940722	M	0.52	0.676	0.858	990923	I	0.575	1.025	1.25	00062	M	0.475	0.575	0.65
930629	M	0.26	0.468	0.442	940722	M	0.312	0.494	0.442	990923	I	0.175	0.425	0.35	00062	M	0.45	0.625	0.725
930629	M	0.312	0.468	0.52	940722	M	0.442	0.624	0.676	990923	I	0.288	0.613	0.575	00062	M	0.75	0.925	1.325
930629	M	0.52	0.702	0.754	940722	M	0.312	0.52	0.572	990923	I	0.2	0.475	0.4	00062	M	0.75	0.975	1.5
930629	M	0.546	0.624	0.78	940722	D	0.416	0.832	0.78	990923	I	0.2	0.475	0.425	00062	M	0.9	1	1.475
930629	M	0.286	0.52	0.546	940722	D	0.52	1.014	1.118	990923	I	0.175	0.475	0.475	00062	M	0.55	0.575	0.8
930629	M	0.39	0.494	0.572	940722	D	0.416	0.676	0.702	990923	I	0.175	0.475	0.35	00062	M	1.2	1.3	2.15
930629	M	0.286	0.468	0.52	940722	D	0.416	0.676	0.676	990923	I	0.15	0.425	0.4	00062	M	0.35	0.45	0.475
930629	M	0.312	0.494	0.52	940722	D	0.39	0.65	0.546	990923	I	0.175	0.275	0.45	00062	M	0.4	0.5	0.575
930629	M	0.39	0.494	0.572	940722	D	0.26	0.598	0.572	990923	I	0.325	0.525	0.55	00062	M	0.175	0.55	0.525
930629	M	0.338	0.52	0.494	940722	D	0.312	0.494	0.546	990923	I	0.35	0.575	0.425	00062	M	0.55	0.6	0.575
930629	M	0.286	0.468	0.416	940722	D	0.442	1.248	1.222	990923	I	0.275	0.6	0.55	00062	M	0.85	0.875	1.425
930629	M	0.286	0.468	0.494	940722	D	0.39	0.598	0.676	990923	I	0.15	0.375	0.325	00062	M	0.55	0.675	0.675
930629	M	0.286	0.416	0.468	940722	D	0.208	0.52	0.26	990923	I	0.2	1.025	0.8	00062	M	0.375	0.425	0.525
930629	M	0.338	1.092	1.144	940722	D	0.26	0.442	0.442	990923	I	0.125	1.05	0.825	00062	M	0.675	0.7	1.025
930629	M	0.416	1.014	0.962	940722	D	0.26	0.624	0.546	990923	I	0.15	0.5	0.45	00062	M	0.8	0.725	1.25
930629	M	0.286	0.468	0.52	940722	D	0.286	0.936	0.754	990923	I	0.15	0.375	0.6	00062	M	0.65	1	1.1
930629	M	0.468	0.598	0.702	940722	D	0.52	1.04	1.118	990923	I	0.175	0.525	0.425	00062	M	0.475	0.6	0.725
930629	M	0.364	0.468	0.52	940722	D	0.65	1.3	1.43	990923	I	0.225	0.45	0.45	00062	M	0.5	0.5	0.525
930629	D	0.286	0.468	0.416	940722	D	0.468	0.91	0.858	990923	I	0.2	0.475	0.45	00062	M	0.775	0.975	1.375

Appendix A. (continued)

1993					1994					1999					2000				
Date	Sit	Head	Body	Tail	Date	Sit	Head	Body	Tail	Date	Site	Head	Body	Tail	Date	Site	Head	Body	Tail
930629	D	0.234	0.468	0.468	940722	D	0.52	1.196	1.352	990923	I	0.188	0.463	0.4	00062	M	0.65	0.6	0.55
930629	D	0.26	0.52	0.468	940722	D	0.442	0.858	0.858	990923	I	0.575	0.9	1.075	00062	M	0.975	0.75	1.35
930629	D	0.416	0.572	0.676	940722	D	0.338	0.702	0.598	990923	I	0.35	0.6	0.4	00062	M	0.975	1	1.4
930629	D	0.494	0.572	0.65	940722	D	0.494	0.884	0.91	990923	I	0.525	0.988	0.95	00062	M	0.525	0.575	0.725
930629	D	0.26	0.442	0.39	940722	D	0.364	0.728	0.65	990923	I	0.2	0.5	0.45	00062	M	0.925	1.05	1.725
930629	D	0.312	0.442	0.416	940722	D	0.26	0.546	0.52	990923	I	0.175	0.475	0.45	00062	M	0.775	0.925	1.5
930629	D	0.312	0.494	0.52	940722	D	0.364	0.702	0.702	990923	I	0.4	0.563	0.388	00062	D	0.3	0.475	0.525
930629	D	0.286	0.52	0.52	940722	D	0.234	0.494	0.494	990923	I	0.225	0.5	0.475	00062	D	0.9	0.875	1.725
930629	D	0.208	0.494	0.468	940722	D	0.26	0.546	0.546	990923	I	0.7	1.15	1.3	00071	I	0.425	0.45	0.5
930629	D	0.286	0.442	0.468	940722	D	0.234	0.442	0.416	990923	I	0.25	0.525	0.225	00071	I	0.55	0.525	0.725
930629	D	0.416	1.092	1.144	940722	D	0.234	0.494	0.468	990923	I	0.188	0.413	0.4	00071	I	0.65	0.8	1.075
930629	D	0.65	1.144	1.066	940722	D	0.494	1.014	1.092	990923	I	0.675	1.175	1.475	00071	I	0.8	0.825	1.225
930629	D	0.312	0.52	0.546	940722	D	0.572	1.378	1.352	990923	I	0.588	1.038	1.325	00071	I	0.325	0.525	0.35
930629	D	0.26	0.468	0.468	940722	D	0.702	1.144	1.43	990923	I	0.6	0.35	0.575	00071	I	0.425	0.325	0.7
930629	D	0.286	0.286	0.494	940818	I	0.624	0.936	1.066	990923	I	0.25	0.375	0.6	00071	I	0.325	0.4	0.45
930629	D	0.234	0.468	0.468	940818	I	0.598	0.806	0.962	990923	I	0.675	1.2	1.275	00071	I	0.575	0.5	0.775
930629	D	0.52	1.092	1.17	940818	I	0.546	0.832	0.988	990923	I	0.35	0.575	0.65	00071	I	0.8	0.85	1.25
930629	D	0.208	0.494	0.52	940818	I	0.338	0.416	0.494	990923	I	0.413	0.863	0.8	00071	I	0.375	0.875	0.95
930629	D	0.234	0.494	0.494	940818	I	0.442	0.65	0.754	990923	I	0.625	1.3	1.575	00071	I	0.45	0.475	0.6
930629	D	0.494	0.728	0.728	940818	I	0.312	0.416	0.286	990923	I	0.7	1.025	1.45	00071	I	0.75	0.85	0.425
930629	D	0.442	1.04	1.092	940818	I	0.286	0.468	0.52	990923	I	0.6	1.05	1.275	00071	I	0.375	0.45	0.575
930629	D	0.416	0.78	0.78	940818	I	0.234	0.39	0.494	990923	I	0.575	1.325	1.55	00071	I	0.175	1.875	1.525
930629	D	0.26	0.442	0.494	940818	I	0.312	0.442	0.52	990923	I	0.65	1.175	1.35	00071	I	0.5	0.575	0.725
930629	D	0.312	0.26	0.494	940818	M	0.312	0.416	0.416	990923	I	0.525	1.075	1.3	00071	I	0.475	0.575	0.65
930629	D	0.468	0.598	0.65	940818	M	0.494	1.066	1.144	990923	I	0.5	1.125	1.275	00071	I	0.375	0.5	0.425
930629	D	0.494	0.702	0.806	940818	M	0.26	0.468	0.494	990923	I	0.2	0.475	0.475	00071	I	0.3	0.425	0.5
930629	D	0.546	0.962	0.91	940818	M	0.78	1.17	1.638	990923	I	0.175	0.5	0.45	00071	I	0.475	0.525	0.7
930629	D	0.26	0.468	0.494	940818	M	0.546	1.04	1.248	990923	M	0.238	0.413	0.425	00071	I	0.325	0.375	0.5
930629	D	0.312	0.52	0.546	940818	M	0.572	1.222	1.326	990923	M	0.575	0.65	0.6	00071	I	0.325	0.4	0.475

Appendix A. (continued)

1993					1994					1999					2000				
Date	Sit	Head	Body	Tail	Date	Sit	Head	Body	Tail	Date	Site	Head	Body	Tail	Date	Site	Head	Body	Tail
930714	I	0.546	0.546	0.572	940818	M	0.338	0.442	0.442	990923	M	0.35	0.75	0.7	00071	I	0.525	0.55	1
930714	I	0.312	0.442	0.442	940818	M	0.26	0.728	0.702	990923	M	0.475	0.575	0.45	00071	I	0.3	0.4	0.5
930714	I	0.312	0.494	0.572	940818	M	0.416	0.78	0.884	990923	M	0.613	0.838	1.075	00071	I	0.575	0.525	0.925
930714	I	0.39	0.65	0.702	940818	M	0.286	0.494	0.52	990923	M	0.65	0.975	1.338	00071	I	0.475	0.575	0.5
930714	I	0.624	1.118	1.222	940818	M	0.156	0.416	0.468	990923	M	0.4	0.525	0.65	00071	I	0.45	0.525	0.6
930714	I	0.468	0.52	0.572	940818	M	0.286	0.468	0.494	990923	M	0.425	0.575	0.625	00071	I	0.6	0.575	1.1
930714	I	0.338	0.598	0.65	940818	M	0.26	0.468	0.494	990923	M	0.375	0.525	0.575	00071	I	0.575	0.65	0.85
930714	I	0.312	0.442	0.416	940818	M	0.572	0.962	0.858	990923	M	0.275	0.375	0.425	00071	I	0.625	0.725	0.9
930714	I	0.208	0.468	0.494	940818	M	0.494	1.092	1.014	990923	M	0.5	0.725	0.8	00071	I	0.65	0.65	0.75
930714	I	0.312	0.442	0.52	940818	M	0.312	0.468	0.572	990923	M	0.25	0.425	0.575	00071	I	0.425	0.65	0.65
930714	I	0.208	0.416	0.442	940818	M	0.572	0.962	1.118	990923	M	1.538	0.738	0.875	00071	I	0.7	0.95	1.225
930714	I	0.338	0.442	0.546	940818	M	0.52	0.988	1.118	990923	M	0.725	0.65	1.025	00071	I	0.625	0.675	0.875
930714	I	0.234	0.65	0.598	940818	M	0.13	0.468	0.442	990923	M	0.65	0.7	1.1	00071	I	0.475	0.65	0.8
930714	I	0.26	0.442	0.442	940818	M	0.442	0.468	0.52	990923	M	0.525	0.825	0.85	00071	I	0.8	0.9	1.225
930714	I	0.26	0.39	0.338	940818	M	0.416	0.598	0.65	990923	M	0.45	0.575	0.65	00071	I	0.625	0.7	0.775
930714	I	0.312	0.468	0.442	940818	M	0.26	0.39	0.468	990923	M	0.25	0.275	0.575	00071	I	0.65	0.675	0.9
930714	I	0.52	0.598	0.598	940818	M	0.364	0.598	0.598	990923	M	0.65	0.6	1.025	00071	I	0.275	0.4	0.5
930714	I	0.728	0.806	1.326	940818	M	0.286	0.442	0.416	990923	M	0.075	0.4	0.4	00071	I	0.75	0.975	1.175
930714	I	0.26	0.546	0.52	940818	M	0.156	0.494	0.442	990923	M	0.375	0.425	0.525	00071	I	0.75	0.625	0.95
930714	I	0.156	0.39	0.442	940818	M	0.442	0.468	0.52	990923	M	0.625	0.75	0.85	00071	I	0.525	0.7	0.95
930714	I	0.26	0.494	0.416	940818	M	0.286	0.442	0.442	990923	M	0.375	0.55	0.5	00071	I	0.55	0.65	0.9
930714	I	0.338	0.442	0.52	940818	D	0.26	0.468	0.494	990923	M	0.25	0.375	0.4	00071	I	0.375	0.375	0.55
930714	I	0.26	0.39	0.442	940818	D	0.26	0.598	0.546	990923	M	0.375	0.8	1.475	00071	I	0.8	0.925	1.375
930714	I	0.286	0.468	0.546	940818	D	0.442	0.78	0.884	990923	M	0.7	0.9	1.225	00071	I	0.275	0.4	0.55

Appendix A. (continued)

1993					1994					1999					2000				
Date	Sit	Head	Body	Tail	Date	Sit	Head	Body	Tail	Date	Site	Head	Body	Tail	Date	Site	Head	Body	Tail
930714	I	0.546	0.988	1.118	940818	D	0.39	1.092	1.3	990923	M	0.275	0.325	0.525	00071	M	0.5	0.525	0.925
930714	I	0.26	0.442	0.468	940818	D	0.546	1.066	1.222	990923	M	0.575	0.725	0.775	00071	M	0.4	0.4	0.75
930714	I	0.26	0.442	0.442	940818	D	0.494	0.78	0.884	990923	M	0.65	0.75	0.975	00071	M	0.463	1.5375	0.525
930714	I	0.312	0.442	0.494	940818	D	0.234	0.546	0.494	990923	M	0.575	0.675	0.8	00071	M	0.45	0.375	0.525
930714	I	0.26	0.442	0.39	940818	D	0.494	1.118	1.3	990923	M	0.45	0.875	0.85	00071	M	0.55	0.7	0.9
930714	I	0.234	0.468	0.52	940818	D	0.442	0.78	0.806	990923	M	0.325	0.5	0.525	00071	M	0.7	0.575	0.9
930714	M	0.286	0.494	0.546	940818	D	0.416	0.832	0.754	990923	M	0.288	0.388	0.5	00071	M	0.675	0.6	0.825
930714	M	0.442	0.65	0.754	940818	D	0.312	0.962	0.962	990923	M	0.275	0.65	0.6	00071	M	0.575	0.475	0.65
930714	M	0.52	0.598	0.884	940818	D	0.416	0.832	0.858	990923	M	0.225	0.45	0.425	00071	M	0.375	0.4	0.65
930714	M	0.13	0.494	0.416	940818	D	0.416	0.624	0.676	990923	M	0.25	0.425	0.45	00071	M	0.475	0.5	0.6
930714	M	0.286	0.494	0.572	940818	D	0.364	0.858	0.884	990923	M	0.55	0.725	0.85	00071	M	0.55	0.525	0.7
930714	M	0.702	1.04	1.3	940818	D	0.286	1.04	0.988	990923	M	0.225	0.425	0.5	00071	M	0.4	0.525	0.45
930714	M	0.52	0.598	0.754	940818	D	0.572	1.118	1.352	990923	M	0.225	0.375	0.425	00071	M	0.35	0.375	0.525
930714	M	0.572	0.988	0.91	940818	D	0.52	1.014	1.118	990923	M	0.25	0.45	0.45	00071	M	0.75	0.675	1.175
930714	M	0.468	1.066	1.196	940818	D	0.286	1.274	1.326	990923	M	0.388	0.488	0.825	00071	M	0.275	0.35	0.425
930714	M	0.494	0.546	0.754	940818	D	0.494	0.754	0.858	990923	M	0.675	0.85	1.075	00071	M	0.525	0.475	0.775
930714	M	0.494	0.832	1.248	940818	D	0.52	1.248	1.326	990923	M	0.625	0.925	1.175	00071	M	0.525	0.475	0.75
930714	M	0.416	0.624	0.754	940818	D	0.364	0.624	0.624	990923	M	0.45	0.525	0.6	00071	M	0.5	0.525	0.725
930714	M	0.312	0.468	0.52	940818	D	0.312	0.624	0.546	990923	M	0.388	0.788	0.775	00071	M	0.6	0.675	0.95
930714	M	0.52	0.832	0.988	940818	D	0.364	0.754	0.91	990923	M	0.6	0.85	1.025	00071	M	0.4	0.5	0.55
930714	M	0.546	0.598	0.832	940818	D	0.39	0.624	0.624	990923	M	0.6	0.55	0.6	00071	M	0.3	0.45	0.525
930714	M	0.676	0.832	1.118	940818	D	0.442	0.728	0.884	990923	M	0.675	0.8	1.075	00071	M	0.425	0.475	0.625
930714	M	0.416	0.754	0.884	940818	D	0.364	0.702	0.728	990923	M	0.425	0.525	0.6	00071	M	0.375	0.425	0.55
930714	M	0.624	1.118	1.352	940818	D	0.676	1.092	1.352	990923	M	0.625	0.7	0.95	00071	M	0.3	0.5	0.35

Appendix A. (continued)

1993					1994					1999					2000				
Date	Sit	Head	Body	Tail	Date	Sit	Head	Body	Tail	Date	Site	Head	Body	Tail	Date	Site	Head	Body	Tail
930714	M	0.26	0.468	0.52	940818	D	0.442	0.806	0.91	990923	D	0.3	0.675	0.15	00071	M	0.55	0.525	0.775
930714	M	0.702	1.014	1.274	940818	D	0.338	0.598	0.65	990923	D	0.675	0.975	1.125	00071	M	0.525	0.75	0.9
930714	M	0.26	0.494	0.52	940818	D	0.208	0.494	0.494	990923	D	0.3	0.425	0.475	00071	M	0.625	0.575	0.8
930714	M	0.312	0.468	0.468	940909	I	0.26	0.676	0.598	990923	D	0.275	0.4	0.475	00071	M	0.375	0.375	0.475
930714	M	0.364	0.572	0.624	940909	I	0.286	0.676	0.598	990923	D	0.375	0.575	0.575	00071	M	0.35	0.425	0.6
930714	M	0.65	0.858	1.118	940909	I	0.598	0.91	1.014	990923	D	0.275	0.425	0.5	00071	M	0.675	0.525	0.8
930714	M	0.65	1.014	1.326	940909	I	0.442	0.936	0.832	990923	D	0.375	0.375	0.45	00071	M	0.35	0.35	0.5
930714	M	0.546	0.988	1.248	940909	I	0.338	0.676	0.598	990923	D	0.325	0.425	0.475	00071	M	0.35	0.375	0.5
930714	M	0.312	0.468	0.52	940909	I	0.312	0.702	0.572	990923	D	0.25	0.375	0.425	00071	M	0.55	0.575	0.775
930714	M	0.286	0.494	0.52	940909	I	0.442	0.624	0.676	990923	D	0.3	0.425	0.525	00071	M	0.6	0.55	0.775
930714	M	0.234	0.468	0.468	940909	I	0.234	0.468	0.494	990923	D	0.225	0.55	0.575	00071	M	0.65	0.65	0.975
930714	M	0.806	1.144	1.612	940909	I	0.312	0.78	0.572	990923	D	0.275	0.675	0.225	00071	M	0.75	0.8	1.3
930727	M	0.858	1.118	1.586	940909	I	0.208	0.676	0.546	990923	D	0.275	0.4	0.45	00071	M	0.35	0.425	0.6
930727	M	0.468	0.806	0.858	940909	I	0.312	0.78	0.572	990923	D	0.375	0.975	0.875	00071	M	0.5	0.675	0.8
930727	M	0.546	0.676	0.806	940909	I	0.468	0.78	0.494	990923	D	0.8	0.975	1.4	00071	M	0.725	0.8	1.25
930727	M	0.364	0.572	0.624	940909	I	0.468	0.884	0.962	990923	D	0.7	0.9	1.175	00071	M	0.75	0.5	1.175
930727	M	0.364	0.728	0.676	940909	I	0.26	0.624	0.468	990923	D	0.9	0.85	1.175	00071	M	0.575	0.7	0.95
930727	M	0.468	0.936	0.832	940909	I	0.208	0.858	0.702	990923	D	0.25	0.425	0.475	00071	M	0.55	0.625	0.725
930727	M	0.364	0.598	0.598	940909	M	0.286	0.494	0.468	990923	D	0.325	0.375	0.525	00071	M	0.65	0.55	0.75
930727	M	0.598	0.806	1.04	940909	M	0.234	0.494	0.494	990923	D	0.3	0.4	0.4	00071	M	0.625	0.85	1.175
930727	M	0.676	0.728	1.092	940909	M	0.208	0.546	0.494	990923	D	0.275	0.45	0.5	00071	M	0.35	0.55	0.6
930727	M	0.442	1.144	1.274	940909	M	0.338	1.118	0.988	990923	D	0.3	0.45	0.725	00071	M	0.475	0.475	0.575
930727	M	0.442	0.598	0.702	940909	M	0.234	0.988	0.78	990923	D	0.25	0.4	0.375	00071	D	0.425	0.5	0.65
930727	M	0.52	0.832	0.91	940909	M	0.052	1.17	0.806	990923	D	0.225	0.55	0.45	00071	D	0.55	0.5	0.75

Appendix A. (continued)

		1993					1994					1999					2000		
Date	Sit	Head	Body	Tail	Date	Sit	Head	Body	Tail	Date	Site	Head	Body	Tail	Date	Site	Head	Body	Tail
930727	M	0.234	0.78	0.65	940909	M	0.156	0.546	0.494	990923	D	0.275	0.4	0.425	00071	D	0.55	0.65	0.9
930727	M	0.832	1.196	1.508	940909	M	0.338	1.222	1.274	990923	D	0.6	0.875	0.925	00071	D	0.275	0.375	0.475
930727	M	0.442	0.572	0.65	940909	M	0.234	0.936	0.936	990923	D	0.475	0.575	0.625	00071	D	0.325	0.375	0.5
930727	M	0.598	0.936	1.17	940909	M	0.338	0.65	0.702	990923	D	0.325	0.425	0.425	00071	D	0.5	0.475	0.675
930727	M	0.494	1.092	1.196	940909	M	0.208	0.546	0.546	990923	D	0.5	0.55	0.65	00071	D	0.525	0.75	1
930727	M	0.442	0.832	0.676	940909	M	0.312	0.702	0.676	990923	D	0.675	0.875	1.375	00071	D	0.625	0.625	0.95
930727	M	0.442	0.572	0.624	940909	M	0.39	0.936	1.014	990923	D	0.5	0.55	0.675	00071	D	0.6	0.65	0.825
930727	M	0.494	0.78	0.962	940909	M	0.156	0.676	0.546	990923	D	0.263	0.388	0.4	00071	D	0.275	0.4	0.475
930727	M	0.286	0.832	0.832	940909	M	0.208	0.572	0.546	990923	D	0.525	0.95	1.175	00071	D	0.275	0.4	0.5
930727	M	0.572	0.91	1.17	940909	M	0.468	0.728	0.676	990923	D	0.25	0.35	0.45	00071	D	0.6	0.65	0.9
930727	M	0.442	0.702	0.728	940909	M	0.182	0.468	0.52	990923	D	0.25	0.425	0.35	00071	D	0.275	0.4	0.475
930727	M	0.494	0.884	1.092	940909	M	0.208	0.546	0.52	990923	D	0.3	0.55	0.425	00071	D	0.625	0.575	0.3
930727	M	0.494	1.092	1.3	940909	M	0.052	0.962	0.702	990923	D	0.425	0.6	0.475	00071	D	0.475	0.55	0.575
930727	M	0.52	0.78	0.91	940909	M	0.26	0.52	0.52	990923	D	0.9	0.9	1.125	00071	D	0.3	0.425	0.475
930727	M	0.546	0.832	1.014	940909	M	0.364	1.014	0.962	990923	D	0.25	0.4	0.45	00071	D	0.55	0.65	0.85
930727	M	0.26	0.468	0.468	940909	M	0.39	0.936	0.884	990923	D	0.25	0.263	0.588	00071	D	0.6	0.825	1.175
930727	M	0.468	0.832	0.936	940909	M	0.208	0.572	0.494	990923	D	0.275	0.4	0.5	00071	D	0.575	0.575	0.75
930727	M	0.728	1.066	1.794	940909	M	0.208	0.546	0.494	990923	D	0.275	0.375	0.375	00071	D	0.45	0.425	0.65
930727	D	0.234	0.494	0.468	940909	M	0.364	1.248	1.196	990923	D	0.275	0.425	0.45	00071	D	0.325	0.4	0.55
930727	D	0.208	0.416	0.416	940909	M	0.338	1.144	0.988	990923	D	0.25	0.4	0.4	00071	D	0.325	0.4	0.375
930727	D	0.39	0.65	0.65	940909	M	0.208	1.352	1.17	990923	D	0.425	0.575	0.575	00071	D	0.525	0.6	0.625
930727	D	0.416	1.248	1.352	940909	M	0.156	0.78	0.598	990923	D	0.275	0.4	0.675	00071	D	0.7	0.65	1.025
930727	D	0.52	0.91	1.014	940909	M	0.468	1.066	1.248	990923	D	0.275	0.275	0.475	00071	D	0.5	0.5	0.55
930727	D	0.338	0.364	0.598	940909	M	0.208	0.78	0.598	990923	D	0.625	0.875	1.2	00071	D	0.6	0.675	0.9
930727	D	0.598	1.248	1.482	940909	D	0.338	0.806	0.754	990923	D	0.475	0.575	0.7	00071	D	0.725	0.625	1.075

Appendix A. (continued)

1993					1994					1999					2000				
Date	Sit	Head	Body	Tail	Date	Sit	Head	Body	Tail	Date	Site	Head	Body	Tail	Date	Site	Head	Body	Tail
930727	D	0.65	1.04	1.43	940909	D	0.364	1.274	0.468	991021	I	0.25	0.425	0.45	00071	D	0.55	0.675	1.05
930727	D	0.208	0.442	0.468	940909	D	0.208	0.754	0.598	991021	I	0.15	0.275	0.525	00071	D	0.575	0.475	0.8
930727	D	0.26	0.52	0.572	940909	D	0.182	0.546	0.52	991021	I	0.35	0.525	0.5	00071	D	0.775	0.625	1.075
930727	D	0.52	0.78	0.806	940909	D	0.208	0.598	0.546	991021	I	0.675	1.125	1.4	00071	D	0.725	0.7	1.15
930727	D	0.702	1.248	1.638	940909	D	0.312	0.598	0.572	991021	I	0.575	0.9	0.775	00071	D	0.325	0.55	0.4
930727	D	0.338	0.468	0.52	940909	D	0.26	0.728	0.598	991021	I	0.55	0.95	1.05	00071	D	0.35	0.375	0.5
930727	D	0.338	0.78	0.832	940909	D	0.26	0.702	0.546	991021	I	0.625	1.125	1.35	00071	D	0.475	0.575	0.65
930727	D	0.702	1.014	1.092	940909	D	0.26	0.91	0.728	991021	I	0.425	0.5	0.55	00071	D	0.7	1.075	1.65
930727	D	0.624	1.092	1.326	940909	D	0.208	0.572	0.26	991021	I	0.55	0.95	1.1	00071	D	0.45	0.525	0.55
930727	D	0.702	1.014	1.3	940909	D	0.234	0.702	0.572	991021	I	0.375	0.825	0.825	00071	D	0.775	0.9	1.65
930727	D	0.598	1.17	1.586	940909	D	0.26	0.806	0.78	991021	M	0.225	0.425	0.425	00071	D	0.6	0.675	0.85
930727	D	0.52	1.04	1.404	940909	D	0.364	1.248	0.494	991021	M	0.3	0.5	0.4	00071	D	0.475	0.5	0.625
930727	D	0.494	0.884	1.222	940909	D	0.156	0.572	0.494	991021	M	0.425	0.675	0.8	00071	D	0.3	0.35	0.475
930727	D	0.312	0.884	0.858	940909	D	0.156	0.78	0.572	991021	M	0.5	0.725	0.85	00071	D	0.775	0.6	0.975
930727	D	0.26	0.468	0.494	940909	D	0.26	1.066	0.832	991021	M	0.175	0.45	0.425	00071	D	0.525	0.65	0.75
930727	D	0.468	0.91	0.936	940909	D	0.338	1.092	0.962	991021	M	0.25	0.45	0.375	00071	D	0.35	0.4	0.475
930727	D	0.442	0.806	0.936	940909	D	0.208	0.624	0.572	991021	M	0.3	0.625	0.6	00071	D	0.5	0.525	0.675
930727	D	0.494	0.884	0.988	940909	D	0.312	0.884	0.754	991021	M	0.2	0.425	0.45	00071	D	0.65	0.625	1.025
930727	D	0.494	0.78	0.884	940909	D	0.312	1.274	1.04	991021	M	0.363	0.538	0.575	00071	D	0.3	0.4	0.45
930727	D	0.416	1.092	1.3	940909	D	0.312	0.624	0.702	991021	M	0.4	0.65	0.775	00071	D	0.6	0.575	0.75
930727	D	0.468	0.806	0.91	940909	D	0.182	0.572	0.442	991021	M	0.3	0.525	0.575	00071	D	0.525	0.475	0.925
930727	D	0.286	0.468	0.572	940909	D	0.286	0.728	0.676	991021	M	0.25	0.45	0.375	00071	D	0.5	0.775	1.125
930727	D	0.702	1.118	1.508	940909	D	0.39	1.378	1.326	991021	M	0.325	0.6	0.4	00071	D	0.775	0.775	1.225
930811	I	0.442	0.624	0.65	940909	D	0.286	0.598	0.572	991021	M	0.375	0.7	0.725	00073	I	0.3	0.675	0.625

Appendix A. (continued)

		1993					1994					1999					2000		
Date	Sit	Head	Body	Tail	Date	Sit	Head	Body	Tail	Date	Site	Head	Body	Tail	Date	Site	Head	Body	Tail
930811	I	0.208	0.442	0.364	940909	D	0.182	0.78	0.572	991021	M	0.6	1.25	1.375	00073	I	0.675	0.625	1
930811	I	0.442	1.274	1.326	940909	D	0.182	0.702	0.546	991021	M	0.363	0.563	0.475	00073	I	0.3	0.275	0.575
930811	I	0.468	0.572	0.65	940909	D	0.234	0.78	0.65	991021	M	0.4	0.7	0.725	00073	I	0.35	0.425	0.5
930811	I	0.26	0.65	0.598	940909	D	0.234	0.702	0.572	991021	M	0.525	0.9	1.05	00073	I	0.575	0.525	0.7
930811	I	0.442	1.092	1.066	940909	D	0.26	0.65	0.572	991021	M	0.35	0.55	0.55	00073	I	0.4	0.45	0.5
930811	I	0.598	0.884	0.988	940930	I	0.156	0.494	0.338	991021	M	0.55	0.725	0.825	00073	I	0.25	0.425	0.475
930811	I	0.26	0.442	0.39	940930	I	0.208	0.442	0.39	991021	M	0.463	1.038	1	00073	I	0.275	0.45	0.5
930811	I	0.52	0.598	0.78	940930	I	0.13	0.468	0.416	991021	M	0.5	1.075	1.075	00073	I	0.525	0.525	0.675
930811	I	0.676	1.3	1.664	940930	I	0.52	0.78	0.936	991021	M	0.3	0.5	0.55	00073	I	0.4	0.425	0.55
930811	I	0.624	0.65	1.326	940930	I	0.13	0.39	0.364	991021	M	0.25	0.575	0.6	00073	I	0.4	0.55	0.575
930811	I	0.468	0.78	0.962	940930	I	0.494	0.858	0.806	991021	M	0.175	0.425	0.3	00073	I	0.35	0.475	0.55
930811	I	0.572	1.17	1.482	940930	I	0.104	0.52	0.39	991021	M	0.175	0.35	0.45	00073	I	0.35	0.425	0.525
930811	I	0.26	0.442	0.468	940930	I	0.13	0.494	0.442	991021	M	0.2	0.425	0.425	00073	I	0.275	0.375	0.45
930811	I	0.286	0.468	0.494	940930	I	0.156	0.546	0.494	991021	M	0.225	0.425	0.425	00073	I	0.5	0.6	0.65
930811	I	0.26	0.39	0.416	940930	I	0.26	0.416	0.416	991021	M	0.475	0.7	0.7	00073	I	0.775	0.7	1.05
930811	I	0.364	0.442	0.468	940930	I	0.234	0.624	0.546	991021	M	0.55	0.875	0.825	00073	I	0.3	0.475	0.525
930811	I	0.754	0.962	1.326	940930	I	0.286	0.442	0.416	991021	M	0.225	0.45	0.45	00073	I	0.45	0.325	0.6
930811	I	0.52	0.624	0.78	940930	I	0.182	0.494	0.494	991021	M	0.6	0.75	0.925	00073	I	0.5	0.525	0.7
930811	I	0.416	0.572	0.598	940930	I	0.468	0.858	0.702	991021	M	0.55	0.95	0.975	00073	I	0.25	0.425	0.475
930811	I	0.364	0.598	0.676	940930	I	0.312	0.572	0.52	991021	M	0.275	0.55	0.425	00073	I	0.45	0.525	0.65
930811	I	0.676	0.858	0.988	940930	I	0.156	0.494	0.468	991021	M	0.375	0.725	0.675	00073	I	0.375	0.55	0.55
930811	I	0.156	0.442	0.39	940930	I	0.39	0.91	0.78	991021	M	0.175	0.375	0.35	00073	I	0.3	0.425	0.575
930811	I	0.26	0.442	0.494	940930	I	0.156	0.468	0.468	991021	M	0.5	0.85	1.075	00073	I	0.15	0.425	0.475
930811	I	0.338	0.468	0.546	940930	I	0.208	0.442	0.468	991021	M	0.2	0.325	0.325	00073	I	0.275	0.4	0.475

Appendix A. (continued)

1993					1994					1999					2000				
Date	Sit	Head	Body	Tail	Date	Sit	Head	Body	Tail	Date	Site	Head	Body	Tail	Date	Site	Head	Body	Tail
930811	I	0.676	0.936	1.222	940930	I	0.13	0.52	0.442	991021	M	0.275	0.55	0.5	00073	I	0.538	0.5375	0.8
930811	I	0.494	0.806	0.91	940930	I	0.39	1.118	0.78	991021	M	0.45	0.7	0.675	00073	I	0.275	0.4	0.475
930811	I	0.624	0.754	1.014	940930	I	0.156	0.494	0.39	991021	M	0.675	1.15	1.475	00073	I	0.3	0.4	0.5
930811	I	0.286	0.442	0.338	940930	I	0.468	0.676	0.572	991021	M	0.725	1.1	1.125	00073	I	0.625	0.5	0.45
930811	I	0.39	0.598	0.572	940930	I	0.442	0.52	0.156	991021	M	0.325	0.8	0.425	00073	I	0.475	0.575	0.675
930811	M	0.416	0.5	0.754	940930	I	0.208	0.676	0.494	991021	M	0.225	0.5	0.55	00073	I	0.475	0.5	0.55
930811	M	0.416	0.5	0.702	940930	M	0.182	0.52	0.468	991021	M	0.2	0.45	0.45	00073	I	0.675	0.7	1.2
930811	M	0.39	0.5	0.624	940930	D	0.286	0.676	0.572	991021	M	0.4	0.75	0.725	00073	I	0.2	0.4	0.425
930811	M	0.832	1.17	1.846	940930	D	0.416	0.936	0.936	991021	M	0.525	0.775	0.85	00073	I	0.3	0.5	0.475
930811	M	0.702	1.144	1.638	940930	D	0.13	0.494	0.468	991021	M	0.75	0.375	0.725	00073	I	0.475	0.425	0.725
930811	M	0.39	0.546	0.572	940930	D	0.338	0.962	0.78	991021	M	0.325	0.65	0.6	00073	I	0.275	0.425	0.475
930811	M	0.728	1.144	1.976	940930	D	0.13	1.04	0.858	991021	D	0.675	1	1.225	00073	I	0.425	0.525	0.675
930811	M	0.572	1.17	1.56	940930	D	0.156	0.832	0.65	991021	D	0.275	0.6	0.575	00073	I	0.55	0.525	0.575
930811	M	0.624	1.248	1.638	941026	M	0.494	1.144	1.274	991021	D	0.55	1	1.175	00073	I	0.275	0.4	0.45
930811	M	0.494	0.884	1.144	941026	M	0.26	0.494	0.572	991021	D	0.55	0.95	1.025	00073	I	0.25	0.425	0.475
930811	M	0.39	0.468	0.624	941026	D	0.26	0.468	0.52	991021	D	0.625	1.2	1.525	00073	I	0.55	0.55	0.675
930811	M	1.884	1.3	1.95	941026	D	0.52	1.014	1.17	991021	D	0.2	0.425	0.45	00073	M	0.575	0.675	0.8
930811	M	0.442	0.676	0.676	941122	M	0.312	0.806	0.754	991021	D	0.55	1.1	0.45	00073	M	0.575	0.575	0.725
930811	M	0.26	0.494	0.39	941122	M	0.338	1.014	0.702	991021	D	0.55	0.95	0.9	00073	M	0.475	0.5	0.6
930811	M	0.26	0.494	0.494	941122	M	0.156	0.494	0.338	991021	D	0.55	1.125	1.35	00073	M	0.625	0.675	0.85
930811	M	0.104	0.442	0.416	941122	M	0.234	0.598	0.52	991021	D	0.25	0.4	0.5	00073	M	0.3	0.35	0.525
930811	M	0.338	0.5	0.676	941122	D	0.676	1.612	1.43	991021	D	0.275	0.625	0.45	00073	M	0.35	0.425	0.525
930811	M	0.39	0.5	0.5	941122	D	0.78	1.378	1.352	991021	D	0.625	1.125	1.15	00073	M	0.45	0.5	0.675
930811	M	0.494	0.884	0.728	941122	D	0.754	1.456	1.794	991021	D	0.325	0.55	0.525	00073	M	0.5	0.6	0.7

Appendix A. (continued)

1993					1994					1999					2000				
Date	Sit	Head	Body	Tail	Date	Sit	Head	Body	Tail	Date	Site	Head	Body	Tail	Date	Site	Head	Body	Tail
930811	M	0.5	1.092	1.43	941122	D	0.26	0.806	0.572	991021	D	0.4	0.825	0.975	00073	M	0.45	0.525	0.6
930811	M	0.39	0.598	0.676	941122	D	0.234	0.572	0.494	991021	D	0.45	0.75	0.775	00073	M	0.25	0.3	0.55
930811	M	0.312	0.468	0.52	941122	D	0.156	0.442	0.26	991021	D	0.55	1.025	1.3	00073	M	0.7	0.85	0.925
930811	M	0.312	0.676	0.572	941122	D	0.26	0.702	0.572	991021	D	0.4	0.525	0.575	00073	M	0.3	0.375	0.55
930811	M	0.676	0.91	1.014	941122	D	0.26	0.624	0.598	991021	D	0.15	0.4	0.375	00073	M	0.275	0.425	0.45
930811	M	0.13	0.962	0.936	941122	D	0.208	0.494	0.442	991021	D	0.25	0.425	0.35	00073	M	0.475	0.55	0.6
930811	M	0.5	0.936	1.04	941122	D	0.806	1.3	1.508	991021	D	0.425	0.925	1.15	00073	M	0.275	0.425	0.475
930811	M	0.572	1.248	1.43	941122	D	0.156	0.494	0.39	991021	D	0.2	0.425	0.4	00073	M	0.15	0.525	0.475
930811	M	0.312	0.78	0.676	941220	M	0.338	1.222	0.65	991021	D	0.7	0.95	1.125	00073	M	0.275	0.325	0.425
930811	M	0.442	0.624	0.702	941220	M	0.26	0.572	0.52	991021	D	0.25	0.55	0.525	00073	M	0.45	0.45	0.375
930811	M	0.234	0.936	0.962	941220	D	0.234	0.78	0.676	991021	D	0.5	0.8	0.825	00073	M	0.6	0.525	0.8
930823	I	0.52	0.624	0.728						991021	D	0.275	0.425	0.525	00073	M	0.55	0.675	0.825
930823	I	0.286	0.442	0.572						991021	D	0.325	0.525	0.5	00073	M	0.275	0.45	0.475
930823	I	0.624	0.728	0.988						991021	D	0.475	0.825	0.975	00073	M	0.35	0.4	0.375
930823	I	0.676	0.91	1.378						991021	D	0.375	0.675	0.825	00073	M	0.475	0.475	0.5
930823	I	0.26	0.468	0.494						991021	D	0.425	0.85	0.85	00073	M	0.525	0.575	0.625
930823	I	0.598	0.832	1.196						991021	D	0.525	1.125	1.225	00073	M	0.6	0.825	0.975
930823	I	0.572	0.598	0.754						991021	D	0.25	0.45	0.425	00073	M	0.4	0.6	0.675
930823	I	0.624	0.702	0.988						991021	D	0.2	0.475	0.4	00073	M	0.45	0.475	0.675
930823	I	0.728	0.754	1.17						991021	D	0.45	0.875	1.05	00073	M	0.6	0.625	0.7
930823	I	0.364	0.52	0.494						991021	D	0.675	0.6	0.825	00073	M	0.4	0.55	0.775
930823	I	0.702	0.754	1.066						991021	D	0.75	1.05	1.675	00073	M	0.425	0.5	0.525
930823	I	0.598	0.65	0.832						991021	D	0.325	0.525	0.625	00073	M	0.5	0.575	0.6
930823	I	0.442	0.702	0.702						991118	I	0.425	0.75	0.775	00073	M	0.325	0.425	0.525

Appendix A. (continued)

1993					1994					1999					2000				
Date	Sit	Head	Body	Tail	Date	Sit	Head	Body	Tail	Date	Site	Head	Body	Tail	Date	Site	Head	Body	Tail
930823	I	0.572	0.624	0.598						991118	I	0.2	0.4	0.425	00073	M	0.375	0.575	0.6
930823	I	0.312	0.416	0.52						991118	I	0.213	1.163	0.35	00073	M	0.625	0.775	1.025
930823	I	0.65	0.858	1.274						991118	I	0.375	0.75	0.675	00073	M	0.525	0.75	-0.93
930823	I	0.858	0.91	1.118						991118	I	0.925	1.475	1.775	00073	M	0.5	0.425	0.65
930823	I	0.494	0.624	0.754						991118	I	0.5	1.3	1.675	00073	M	0.875	1.05	1.35
930823	I	0.312	0.442	0.624						991118	I	0.8	1.3	1.7	00073	M	0.45	0.7	0.85
930823	I	0.26	0.468	0.494						991118	I	0.725	0.75	1.525	00073	M	0.5	0.85	1.05
930823	I	0.364	0.364	0.546						991118	M	0.2	0.425	0.425	00073	M	0.625	0.875	1.125
930823	I	0.754	0.936	1.508						991118	M	0.625	1.05	1.225	00073	M	0.325	0.425	0.5
930823	I	0.338	0.442	0.806						991118	M	0.225	0.675	0.425	00073	M	0.55	0.55	0.65
930823	I	0.286	0.364	0.468						991118	M	0.3	0.525	0.6	00073	D	0.375	0.4	0.625
930823	I	0.806	1.092	1.56						991118	M	0.5	0.8	1	00073	D	0.35	0.425	0.55
930823	I	0.624	0.728	1.066						991118	M	0.375	0.8	0.7	00073	D	1	0.95	1.625
930823	I	0.728	0.832	1.274						991118	M	0.5	0.825	0.925	00073	D	0.6	0.55	0.75
930823	I	0.364	0.468	0.546						991118	M	0.7	0.9	0.9	00073	D	0.625	0.5	0.975
930823	I	0.832	0.858	1.43						991118	M	0.25	0.5	0.525	00073	D	0.275	0.45	0.5
930823	I	0.884	0.988	1.404						991118	M	0.575	1	1.15	00073	D	0.7	0.925	1.125
930823	M	0.234	0.936	0.962						991118	M	0.225	0.45	0.3	00073	D	0.275	0.375	0.5
930823	M	0.182	0.312	0.26						991118	M	1	1.15	1.475	00073	D	0.5	0.4	0.3
930823	M	0.5	0.91	1.014						991118	M	0.45	0.775	0.7	00073	D	0.1	0.5	0.35
930823	M	0.286	0.364	0.364						991118	M	0.325	0.625	0.5	00073	D	0.55	0.575	0.85
930823	M	0.234	0.91	0.728						991118	M	0.275	0.575	0.6	00073	D	0.325	0.375	0.5
930823	M	0.702	0.884	1.378						991118	M	0.5	0.225	0.45	00073	D	0.575	0.55	0.8
930823	M	0.416	0.598	0.572						991118	M	0.475	0.75	0.8	00073	D	0.8	0.9	1.35

Appendix A. (continued)

1993					1994					1999					2000				
Date	Sit	Head	Body	Tail	Date	Sit	Head	Body	Tail	Date	Site	Head	Body	Tail	Date	Site	Head	Body	Tail
930823	M	0.338	0.546	0.494						991118	M	0.525	0.775	0.75	00073	D	0.225	0.425	0.45
930823	M	0.702	0.962	1.222						991118	M	0.45	0.975	1.15	00073	D	0.65	0.9	1.375
930823	M	0.598	1.04	1.482						991118	M	0.3	0.575	0.575	00073	D	0.825	0.95	1.825
930823	M	0.728	0.884	1.274						991118	M	0.45	0.725	0.75	00073	D	0.7	0.875	1.7
930823	M	0.442	0.598	0.702						991118	M	0.55	1.05	1.225	00073	D	0.5	0.9	1.1
930823	M	0.728	0.962	1.326						991118	M	0.375	0.675	0.625	00073	D	0.275	0.425	0.375
930823	M	0.494	0.5	0.728						991118	M	0.5	0.975	1.025	00073	D	0.5	0.85	1.125
930823	M	0.858	0.91	1.508						991118	M	0.875	1.15	1.325	00073	D	0.675	0.9	1.675
930823	M	0.78	1.066	1.612						991118	M	0.4	0.825	1	00073	D	0.375	0.475	0.525
930823	M	0.624	0.858	1.222						991118	M	0.5	0.85	0.95	00073	D	0.65	0.825	1.325
930823	M	0.884	1.04	1.586						991118	M	0.35	0.65	0.75	00073	D	0.788	0.9	1.3
930823	M	0.546	0.624	0.806						991118	M	0.8	1.375	1.95	00073	D	0.725	0.85	1.35
930823	M	0.39	0.39	0.598						991118	M	0.225	0.5	0.375	00073	D	0.4	0.5	0.575
930823	M	0.312	0.364	0.416						991118	M	0.25	0.625	0.55	00073	D	0.225	0.5	0.3
930823	M	0.26	0.39	0.494						991118	M	0.85	1.275	1.45	00073	D	0.275	0.45	0.6
930823	M	0.13	0.936	0.5						991118	M	0.6	1.05	1.275	00073	D	0.275	0.425	0.4
930823	M	0.364	0.468	0.546						991118	D	0.525	0.925	0.975	00073	D	0.6	0.8	0.8
930823	M	0.312	0.416	0.546						991118	D	0.45	0.725	0.75	00073	D	0.25	0.425	0.475
930823	M	0.39	0.468	0.572						991118	D	0.25	0.45	0.425	00073	D	0.275	0.375	0.575
930823	M	0.338	0.48	0.598						991118	D	0.6	1.125	1.4	00073	D	0.625	0.7	1
930823	M	0.338	0.442	0.546						991118	D	0.15	0.5	0.375	00073	D	0.775	0.925	1.325
930823	M	0.338	0.468	0.598						991118	D	0.35	0.475	0.675	00073	D	0.75	0.875	1.375
930823	M	0.312	0.468	0.494						991118	D	0.3	0.575	0.475	00073	D	0.35	0.425	0.4
930823	D	0.338	0.572	0.598						991118	D	0.663	1.163	1.4	00073	D	0.6	0.825	1.125

Appendix A. (continued)

1993					1994					1999					2000				
Date	Sit	Head	Body	Tail	Date	Sit	Head	Body	Tail	Date	Site	Head	Body	Tail	Date	Site	Head	Body	Tail
930823	D	0.702	0.936	1.3						991118	D	0.325	0.575	0.6	00073	D	0.6	0.95	1.275
930823	D	0.806	1.066	1.508						991118	D	0.4	0.75	0.575	00073	D	0.45	0.375	0.5
930823	D	0.676	0.962	1.326						991118	D	0.575	0.775	0.85	00073	D	0.325	0.4	0.425
930823	D	0.598	0.728	0.988						991118	D	0.488	0.838	0.825	00081	M	0.3	0.375	0.475
930823	D	0.624	0.806	1.014						991118	D	0.8	1.275	1.625	00081	M	0.3	0.375	0.475
930823	D	0.728	0.962	1.274						991118	D	0.263	0.438	0.425	00081	M	0.525	0.525	0.5
930823	D	0.78	1.014	1.352						991118	D	0.125	1.55	0.675	00081	M	0.45	0.55	0.65
930823	D	0.65	0.988	1.43						991118	D	1.025	1.325	1.425	00081	M	0.35	0.45	0.45
930823	D	0.286	0.468	0.494						991118	D	0.475	0.8	0.825	00081	M	0.525	0.525	0.775
930823	D	0.208	0.39	0.416						991118	D	0.575	0.675	0.85	00081	M	0.5	0.45	0.775
930823	D	0.442	0.572	0.702						991118	D	0.2	0.525	0.35	00081	M	0.3	0.4	0.45
930823	D	0.702	0.936	1.534						991118	D	0.375	0.575	0.5	00081	M	0.25	0.425	0.475
930823	D	0.728	0.91	0.91						991118	D	0.6	1	1.075	00081	M	0.35	0.375	0.925
930823	D	0.598	1.118	1.456						991118	D	0.8	1.125	1.35	00081	M	0.6	0.55	0.825
930823	D	0.65	1.196	1.482						991118	D	0.375	0.575	0.525	00081	M	0.425	0.375	0.675
930823	D	0.572	0.962	1.352						991118	D	0.5	0.825	0.875	00081	M	0.35	0.35	0.575
930823	D	0.286	0.546	0.572						991118	D	0.325	0.45	0.7	00081	M	0.325	0.55	0.325
930823	D	0.624	0.91	1.222						991118	D	0.5	0.7	0.85	00081	M	0.325	0.3	0.525
930823	D	0.572	0.988	1.17						991118	D	0.4	0.8	0.725	00081	M	0.525	0.475	0.8
930823	D	0.702	0.91	1.248						991118	D	0.175	0.775	0.65	00081	M	0.475	0.525	0.675
930823	D	0.338	0.416	0.572						991118	D	0.225	0.4	0.375	00081	M	0.525	0.525	0.675
930823	D	0.676	0.988	1.326						991118	D	0.55	1	0.75	00081	M	0.325	0.4	0.45
930823	D	0.702	0.936	1.274						991118	D	0.825	1.075	1.45	00081	M	0.55	0.55	0.725
930823	D	0.936	0.936	1.586											00081	M	0.325	0.375	0.4

Appendix A. (continued)

1993					1994					1999					2000				
Date	Sit	Head	Body	Tail	Date	Sit	Head	Body	Tail	Date	Site	Head	Body	Tail	Date	Site	Head	Body	Tail
930823	D	0.468	0.78	1.04											00081	M	0.25	0.375	0.4
930823	D	0.546	0.572	0.78											00081	M	0.275	0.225	0.6
930823	D	0.754	0.988	1.534											00081	M	0.35	0.375	0.525
930823	D	0.65	1.014	1.222											00081	M	0.4	0.475	0.625
930823	D	0.65	0.91	1.3											00081	M	0.325	0.4	0.65
930910	I	0.208	0.416	0.338											00081	M	0.45	0.6	0.725
930910	I	0.624	0.988	1.066											00081	M	0.325	0.475	0.625
930910	I	0.234	0.364	0.338											00081	M	0.475	0.5	0.725
930910	I	0.26	0.442	0.442											00081	M	0.325	0.4	0.6
930910	I	0.39	0.598	0.572											00081	M	0.5	0.5	0.825
930910	I	0.286	0.624	0.546											00081	D	0.375	0.25	0.525
930910	I	0.416	0.754	0.728											00081	D	0.4	0.55	0.65
930910	I	0.234	0.598	0.442											00081	D	0.65	0.675	1.05
930910	I	0.416	0.624	0.572											00081	D	0.35	0.425	0.475
930910	I	0.702	0.91	1.092											00081	D	0.425	0.575	0.65
930910	I	0.156	0.39	0.546											00081	D	0.65	0.675	1.025
930910	I	0.234	0.416	0.442											00081	D	0.325	0.4	0.425
930910	M	0.65	0.78	0.962											00081	D	0.475	0.65	0.775
930910	M	0.754	0.936	1.352											00081	D	0.45	0.65	0.7
930910	M	0.624	1.066	1.014											00081	D	0.625	0.675	0.85
930910	M	0.572	0.728	0.988											00081	D	0.5	0.775	0.9
930910	M	0.546	0.728	0.962											00081	D	0.65	0.9	1.2
930910	M	0.468	0.598	0.676											00081	D	0.6	0.8	0.925
930910	M	0.65	0.806	1.092											00081	D	0.5	0.525	0.7

Appendix A. (continued)

1993					1994					1999					2000				
Date	Sit	Head	Body	Tail	Date	Sit	Head	Body	Tail	Date	Site	Head	Body	Tail	Date	Site	Head	Body	Tail
930910	M	0.52	0.754	0.936											00081	D	0.45	0.85	0.95
930910	M	0.754	1.04	0.962											00081	D	0.5	0.55	0.6
930910	M	0.286	0.676	0.676											00081	D	0.45	0.6	0.475
930910	M	0.91	1.144	1.846											00081	D	0.5	0.5	0.7
930910	M	0.78	1.248	1.664											00081	D	0.575	0.55	0.725
930910	M	0.572	0.91	1.144											00081	D	0.45	0.525	0.65
930910	M	0.468	0.806	0.91											00081	D	0.425	0.675	0.75
930910	M	0.442	0.728	0.806											00081	D	0.425	0.5	0.575
930910	M	0.728	0.988	1.612											00081	D	0.325	0.525	0.525
930910	M	0.702	0.91	1.092											00081	D	0.3	0.775	0.75
930910	M	0.572	0.754	0.728											00081	D	0.55	0.675	0.85
930910	M	0.494	0.936	0.754											00081	D	0.575	0.55	0.65
930910	M	0.416	0.546	0.624											00081	D	0.425	0.625	0.5
930910	M	0.832	1.274	1.82											00081	D	0.325	0.525	0.5
930910	M	0.702	1.118	1.378											00081	D	0.4	0.45	0.625
930910	M	0.468	0.598	0.546											00081	D	0.475	0.625	0.7
930910	M	0.728	0.936	1.482											00081	D	0.775	0.7	0.875
930910	M	0.26	0.442	0.416											00081	D	0.2	0.375	0.35
930910	M	0.364	0.598	0.572											00081	D	0.675	0.875	1.3
930910	M	0.494	0.572	0.78											00081	D	0.4	0.45	0.65
930910	M	0.676	1.118	1.352											00081	D	0.5	0.55	0.7
930910	M	0.442	0.572	0.52											00081	D	0.225	0.375	0.425
930910	M	0.442	0.754	0.754											00081	D	0.5	0.5	0.6
930910	D	0.52	0.78	0.858											00081	D	0.55	0.6	0.85

Appendix A. (continued)

1993					1994					1999					2000				
Date	Sit	Head	Body	Tail	Date	Sit	Head	Body	Tail	Date	Site	Head	Body	Tail	Date	Site	Head	Body	Tail
930910	D	0.598	1.17	1.274											00081	D	0.425	0.5	0.55
930910	D	0.832	1.066	1.586											00081	D	0.475	0.45	0.575
930910	D	0.702	1.066	1.352											00081	D	0.5	0.5	0.45
930910	D	0.572	1.014	1.144											00081	D	0.35	0.65	0.925
930910	D	0.598	1.118	1.3											00081	D	0.525	0.675	0.7
930910	D	0.676	0.806	1.014											00081	D	0.85	1.025	1.575
930910	D	0.624	1.248	1.378											00081	D	0.375	0.725	1.025
930910	D	0.702	1.144	1.352											00081	D	0.575	0.5	0.675
930910	D	0.442	0.676	0.754											00081	D	0.725	0.925	1.375
930910	D	0.91	1.3	1.924											00081	D	0.5	0.65	0.9
930910	D	0.624	1.118	1.378											00081	D	0.65	0.7	1.1
930910	D	0.546	0.988	1.17											00083	I	0.85	0.95	1.55
930910	D	0.676	1.014	1.404											00083	I	0.75	0.925	1.375
930910	D	0.598	1.066	1.3											00083	I	0.625	0.725	0.925
930910	D	0.78	1.092	1.482											00083	I	0.65	0.575	0.8
930910	D	0.598	1.196	1.352											00083	I	0.775	0.9	1.5
930910	D	0.468	0.806	0.962											00083	I	0.725	0.9	1.375
930910	D	0.78	1.17	1.534											00083	I	0.75	0.975	1.375
930910	D	0.806	1.118	1.638											00083	I	0.725	1	1.375
930910	D	1.066	1.3	2.132											00083	I	0.4	0.55	0.675
930910	D	0.806	1.352	1.794											00083	M	0.75	0.9	1.375
930910	D	0.494	0.78	0.832											00083	M	0.725	0.9	1.25
930910	D	0.286	0.624	0.494											00083	M	0.85	0.925	1.675
930910	D	0.338	0.442	0.416											00083	M	0.75	1.05	1.175

Appendix A. (continued)

1993					1994					1999					2000				
Date	Sit	Head	Body	Tail	Date	Sit	Head	Body	Tail	Date	Site	Head	Body	Tail	Date	Site	Head	Body	Tail
930910	D	0.572	0.858	0.962											00083	M	0.425	0.225	0.45
930910	D	0.39	1.092	1.352											00083	M	0.825	0.75	0.9
930910	D	0.858	1.274	1.82											00083	M	0.625	0.825	1.05
930910	D	0.78	1.274	1.56											00083	M	0.75	0.85	1.325
930910	D	0.754	0.988	1.456											00083	M	0.675	0.9	1.3
930918	M	0.52	0.78	0.858											00083	M	0.55	0.875	1.125
930918	M	0.338	0.676	0.728											00083	M	0.6	0.85	1.175
930918	M	0.832	1.534	2.028											00083	M	0.65	0.85	1.15
930918	M	0.728	0.806	1.17											00083	M	0.275	0.375	0.45
930918	M	0.598	0.936	1.248											00083	M	0.75	0.75	1.225
930918	M	0.728	0.832	1.118											00083	M	0.75	0.775	1.125
930918	M	0.234	0.494	0.52											00083	M	0.725	0.75	1.175
930918	M	0.884	1.534	1.95											00083	M	0.775	1.2	1.675
930918	M	0.442	0.832	0.936											00083	M	0.525	0.475	0.625
930918	M	0.572	1.014	1.198											00083	M	0.85	0.825	1.05
930918	M	0.572	0.858	1.198											00083	D	0.55	0.8	1.2
930918	M	0.676	0.988	1.04											00083	D	0.375	0.7	0.875
930918	M	0.416	0.65	0.468											00083	D	0.6	0.7	0.7
930918	M	0.26	0.468	0.468											00083	D	0.35	0.25	0.675
930918	M	0.936	1.534	2.08											00083	D	0.65	0.7	0.925
930918	M	0.208	0.468	0.338											00083	D	0.55	0.475	0.6
930918	M	0.39	0.546	0.494											00083	D	0.675	0.925	1.225
930918	D	0.598	1.248	1.56											00083	D	0.35	0.475	0.725
930918	D	0.702	1.17	1.456											00083	D	0.275	0.35	0.525

Appendix A. (continued)

1993					1994					1999					2000				
Date	Sit	Head	Body	Tail	Date	Sit	Head	Body	Tail	Date	Site	Head	Body	Tail	Date	Site	Head	Body	Tail
930918	D	0.182	0.39	0.364											00083	D	0.45	0.525	0.85
930918	D	1.066	1.43	2.34											00083	D	0.475	0.525	0.6
930918	D	0.182	0.468	0.416											00083	D	0.55	0.675	0.975
930918	D	0.234	0.468	0.39											00083	D	0.7	0.85	1
930918	D	0.39	0.78	0.884											00083	D	0.675	0.825	1.075
930918	D	0.546	1.066	1.196											00083	D	0.275	0.45	0.7
930918	D	0.676	1.222	1.56											00083	D	0.575	0.65	1.125
930918	D	0.806	1.274	1.924											00083	D	0.275	0.375	0.5
930918	D	0.208	0.468	0.494											00083	D	0.45	0.5	0.65
930918	D	0.26	0.442	0.52											00083	D	0.325	0.4	0.525
930918	D	0.572	1.144	1.378											00083	D	0.525	0.75	1.075
930918	D	0.182	0.468	0.39											00083	D	0.5	0.675	0.8
930918	D	0.702	1.17	1.3											00083	D	0.675	0.85	1.45
930918	D	0.312	0.962	1.014											00083	D	0.75	0.625	1.3
930918	D	0.546	0.884	0.832											00083	D	0.375	0.625	0.55
930918	D	0.806	1.066	1.456											00083	D	0.55	0.625	0.75
930918	D	0.754	1.586	1.924											00083	D	0.725	0.65	1.225
930918	D	0.728	1.17	1.456											00083	D	0.625	0.55	0.825
931023	M	0.624	1.326	1.534											00083	D	0.55	0.95	1.225
931023	D	0.676	0.988	1.404											00083	D	0.525	0.45	0.675
931023	D	0.65	1.222	1.82											00083	D	0.6	0.85	1.15
931023	D	0.26	0.65	0.676											00091	I	0.75	0.725	1.025
															00091	I	0.7	0.75	0.775
															00091	I	0.725	0.75	0.875

Appendix A. (continued)

1993					1994					1999					2000				
Date	Sit	Head	Body	Tail	Date	Sit	Head	Body	Tail	Date	Site	Head	Body	Tail	Date	Site	Head	Body	Tail
															00091	I	0.525	0.575	0.925
															00091	I	0.475	0.525	0.675
															00091	I	0.65	0.4	0.725
															00091	I	0.675	0.775	0.95
															00091	M	0.25	0.375	0.5
															00091	M	0.675	0.725	0.975
															00091	M	0.325	0.425	0.45
															00091	M	0.325	0.425	0.525
															00091	M	0.475	0.525	0.65
															00091	M	0.375	0.375	0.525
															00091	M	0.325	0.575	0.6
															00091	M	0.775	1.15	1.625
															00091	M	0.25	0.4	0.425
															00091	M	0.575	0.525	0.75
															00091	M	0.35	0.45	0.55
															00091	M	0.2	0.25	0.425
															00091	M	0.45	0.525	0.725
															00091	M	0.375	0.35	0.55
															00091	M	0.625	0.65	0.825
															00091	M	0.4	0.4	0.375
															00091	M	0.675	0.725	0.85
															00091	M	0.7	0.8	1.25
															00091	M	0.375	0.6	0.575
															00091	M	0.3	0.425	0.425

Appendix A. (continued)

1993					1994					1999					2000				
Date	Sit	Head	Body	Tail	Date	Sit	Head	Body	Tail	Date	Site	Head	Body	Tail	Date	Site	Head	Body	Tail
															00091	M	0.35	0.3	0.55
															00091	M	0.525	0.525	0.7
															00091	M	0.425	0.425	0.575
															00091	M	0.3	0.425	0.5
															00091	M	0.325	0.425	0.45
															00091	M	0.35	0.4	0.425
															00091	M	0.425	0.425	0.6
															00091	M	0.3	0.425	0.55
															00091	M	0.65	0.725	0.725
															00091	M	0.525	0.475	0.425
															00091	D	0.375	0.45	0.5
															00091	D	0.45	0.475	0.6
															00091	D	0.45	0.575	0.675
															00091	D	0.65	0.675	0.9
															00091	D	0.925	1.25	1.775
															00091	D	0.625	0.675	0.825
															00091	D	0.6	0.75	0.875
															00091	D	0.5	0.775	0.85
															00091	D	0.325	0.725	0.775
															00091	D	0.45	0.825	1.2
															00091	D	0.7	0.975	1.6
															00091	D	0.275	0.375	0.325
															00091	D	0.275	0.35	0.5
															00091	D	0.3	0.4	0.35

Appendix A. (continued)

1993					1994					1999					2000				
Date	Sit	Head	Body	Tail	Date	Sit	Head	Body	Tail	Date	Site	Head	Body	Tail	Date	Site	Head	Body	Tail
															00091	D	0.4	0.55	0.625
															00091	D	0.5	0.8	1
															00091	D	0.675	0.825	1.2
															00091	D	0.475	0.525	0.675
															00091	D	0.325	0.425	0.5
															00091	D	0.575	0.925	1.15
															00091	D	0.475	0.925	1.25
															00091	D	0.85	1.1	1.525
															00091	D	0.45	0.9	1.2
															00091	D	0.3	1.025	1.6
															00091	D	0.625	0.875	1.175
															00091	D	0.775	0.75	1.275
															00091	D	0.25	0.425	0.45
															00091	D	0.525	0.9	1.125
															00091	D	0.475	0.375	0.675
															00091	D	0.475	0.575	0.7

Appendix B. Varriables used for PCA analysis. Avg (average), I (Inflow), M (Midlake), D (Dam), Ds (Dissolved), Ss (Suspended), Cnduct (Conductivity) ratios are arcsin transformed.

Date	Site	Avg Head Ratio	Avg Body Ratio	Avg Tail Ratio	Ds Solids (mg L -1)	Ss Solids (mg L -1)	Secchi Depth (cm)	pH	Temp (oC)	DO (mg L -1)	Alkalinity CaCO3 (mg L-1)	Nitrogen NO3+NO2 (mg L -1)	Chl a (mg m-3)	Cnduct umho (cm -1)	Ds PO4-P (mg L-1)	Ss PO4-P (mg L-1)
930525	M	0.2299	0.3895	0.4032	244	65.9	27	7.3	24	11.4	112.3	4.9	32.4	440	0.091	0.067
930525	D	0.2025	0.4025	0.4193	270.8	53.7	27	6	19	8	105.6	5.4	57.6	440	0.126	0.054
930614	M	0.2343	0.3462	0.4429	305	45	19	6	25	7.2	113.3	5.3	113.4	450	0.114	0.127
930629	M	0.2382	0.3788	0.4057	210	165	41	6.4	27	7.4	122.9	2.9	18.5	470	0.103	0.044
930629	D	0.2267	0.3874	0.4094	190	155	43	6.3	27	6.9	121.0	3.1	42.2	470	0.045	0.054
930714	I	0.2354	0.3813	0.406	317.5	52.5	25	6.5	29	9.6	88.3	1.2	26.7	520	0.052	0.07
930714	M	0.2267	0.3643	0.4328	292.5	27.5	55	6.4	28	8.1	113.3	2.2	17.8	480	0.052	0.067
930727	M	0.2215	0.3756	0.4271	172.5	40	61	6.6	29	10.2	113.8	0.9	2.7	480	0.058	0
930727	D	0.2049	0.3784	0.4418	195	17.5	60	6.4	28	9.7	112.3	1.1	5.3	480	0.021	0.071
930811	I	0.2327	0.3741	0.4167	252.5	50	30	6.7	28	11.1	73.9	0.6	26.7	340	0.094	0.153
930811	M	0.219	0.377	0.4381	240	82.5	53	6.5	28	10.3	81.6	0.6	8	430	0.072	0.101
930823	I	0.2592	0.3263	0.4376	102.5	92.5	27	6.6	28	7	97.0	0.2	32	390		0.234
930823	M	0.2419	0.3568	0.4257	70	85	47	6.9	28	6.1	104.6	0.1	10.7	430	0.058	0.026
930823	D	0.2344	0.339	0.4507	87.5	80	48	6.5	27	6.1	113.3	0.2	8	430	0.105	0.024
930910	I	0.2228	0.4043	0.3968	135	112.5	23	6.8	22	3.9	111.4	1.4	21.4	260	0.157	0.125
930910	M	0.2431	0.358	0.4221	117.5	82.5	25	6.9	23	3.9	121.0	1.2	16	280	0.168	0.07
930910	D	0.2205	0.3594	0.4445	120	122.5	28	6.8	23	2	115.2	0.7	26.7	280	0.115	0.115
930918	M	0.2258	0.3768	0.4215	134.5	53	52	6.2	19	5.4	79.7	1.4	13.4	280	0.178	0.057
930918	D	0.199	0.3865	0.4401	123.2	46.8	51	6.9	18	2.3	84.5	1.9	10.7	280	0.202	0.019
931023	M	0.1801	0.3904	0.4559	261.5	21	39		14	8.1	114.0	4	10.68	430	0.202	0.128
931023	D	0.1907	0.3685	0.4678	235.5	17	39		14	9.2	139.2	3.6	0	430	0.088	0.057
990923	I	0.1957	0.415	0.4159	316	59	24	8.38	17.4	7.8	126.1	0.017	1.98	352.6		0.281
990923	M	0.2525	0.3511	0.4199	342	58	46	8.64	19.3	9.5	111.6	0.003	36.69	387.7		0.178
990923	D	0.2492	0.3689	0.4058	483	67	38	8.16	18.8	6.8	111.6	0.108	17.44	340.1		0.192
991021	I	0.2223	0.3736	0.4287	188	62	28	8.29	11.9	8.7	131.0	0.013	13.26	307.6	0.026	0.121
991021	M	0.2222	0.4008	0.401	142	83	40	8.55	14	9.64	121.3	0.002	5.78	310.4	0.016	0.112
991021	D	0.2154	0.3931	0.4161	110	89	45	8.44	14	9.56	135.8	0.036	12.24	310.5	0.018	0.106
991118	I	0.1967	0.4139	0.4205	200	50	32	8.32	9	10.02	140.7	0.004	56.69	299.3	0.066	0.191
991118	M	0.2231	0.3913	0.4099	145	30	39	8.34	10.5	9.01	135.8	0	13.22	296.3	0.132	0.035
991118	D	0.2203	0.4054	0.3995	62	13	59	8.33	10.9	8.92	135.8	0.004	11.82	297.2	0.05	0.082
000629	M	0.2761	0.3246	0.4218	170	30	35	8.89	27.1	13.71	118.2	0.094	117.4	349	0.096	0.016
000629	D	0.2465	0.3134	0.4655	197	13	47	8.7	26.8	10.68	153.4	0.024	40.59	431	0.01	0.157

Appendix B. (continued)

Date	Site	Avg Head Ratio	Avg Body Ratio	Avg Tail Ratio	Ds Solids ($mg\ L^{-1}$)	Ss Solids ($mg\ L^{-1}$)	Secchi Depth (cm)	pH	Temp (^{o}C)	DO ($mg\ L^{-1}$)	Alkalinity $CaCO_3$ ($mg\ L^{-1}$)	Nitrogen NO_3+NO_2 ($mg\ L^{-1}$)	Chl a (mg^{m-3})	Cnduct umho (cm^{-1})	Ds PO_4-P ($mg\ L^{-1}$)	Ss PO_4-P ($mg\ L^{-1}$)
000712	I	0.2733	0.3325	0.4169	143	47	27	8.66	28.5	7.64	105.6	0.18	112.98	327.5	0.049	0.196
000712	M	0.2858	0.3159	0.4211	117	23	47	9.03	29.3	10.19	110.7	0.015	88.14	331.5	0.071	0.067
000712	D	0.2819	0.3176	0.4229	51	19	54	8.56	29	6.29	120.7	0.025	51.29	370.3	0.043	0.089
000730	I	0.2682	0.3381	0.4161	179	11	25	8.36	25.6	4.78	125.8	0.295	76.84	351.9	0.083	0.212
000730	M	0.2726	0.3389	0.4104	121	9	40	8.31	25.8	5.72	120.7	0.17	54.99	343.6	0.059	0.111
000730	D	0.2551	0.3349	0.4342	93	7	49	8.31	26.5	4.84	93.1	0.091	48.92	347.2	0.026	0.065
000816	M	0.2749	0.3149	0.4336	102	8	45	8.66	27.5	6.82	118.2	0.006	60.59	358.4	0.072	0.13
000816	D	0.2716	0.3288	0.4222	52	8	54	8.74	27.6	5.18	115.7	0.012	70.41	354.9	0.091	0.066
000831	I	0.2589	0.3104	0.4544	166.6	3.4	31	8.94	30.3	9.55	125.8	0.009	58.09	386.3	0.104	0.132
000831	M	0.2709	0.3091	0.4433	107.7	2.3	43	8.84	30.3	11.09	120.7	0.012	63.54	373.5	0.104	0.106
000831	D	0.2605	0.3141	0.4493	18.6	1.4	63	9.04	31	11.77	115.7	0.015	58.23	367.3	0.086	0.094
000914	I	0.3069	0.3037	0.4109			21	9.27	22.6	5.47	130.8	0.034	63.54	311.2	0.09	0.187
000914	M	0.2786	0.3301	0.4133			34	8.83	24.5	6.99	130.8	0.022	54.05	341.5	0.11	0.12
000914	D	0.2447	0.3403	0.4389			41	8.88	25.6	8.16	120.7	0.021	79.65	345.2	0.148	0.095
940701	I	0.2165	0.3794	0.4277	203	72	10	7.2	27.5	5.3	110.4	4.41	19.58	330	0.042	0.052
940701	D	0.2184	0.3932	0.4129	239.8	22.7	11	6.7	26.5	5.7	74.4	6.92	7.12	250	0.098	0.062
940722	M	0.2473	0.372	0.4028	196	24	30	7.5	30	6.4	114.24	4.4	28.48	300	0.078	0.119
940722	D	0.2032	0.4172	0.4045	92.5	34	30	7.7	28.5	9.4	98.88	4.11	218.94	290	0.282	0.058
940818	I	0.2491	0.3645	0.4089	230	75	17	8.6	28	9	138.24	0.12	144.18	340	0.012	0.339
940818	M	0.2195	0.3897	0.4148	180.5	17	39	8.9	28	12.8	105.6	0.345	67.64	270	0.012	0.081
940818	D	0.1944	0.4023	0.4288	77.5	100	46	9.1	26.5	13.7	95	0.715	129.94	280	0.012	0.518
940909	I	0.2184	0.4131	0.3931	281	59	14	8.2	24.8	7.9	136.32	0.012	5.34	320	0.003	0.004
940909	M	0.1479	0.4618	0.4203	241.5	21	30	7.5	23	6.7	127.68	0.27	21.36	320	0.003	0.001
940909	D	0.1543	0.4895	0.3871	229.5	13	30	7.4	22.8	6.4	114.24		80.1	290	0.003	0
940930	I	0.1866	0.4545	0.3865	300	60	10	8.4	9	10.5	134.4	0.104	32.04	330	0.001	0.001
940930	M	0.1562	0.4606	0.4115	298	32	27	8.3	19.5	9.2	124.8	0.439	21.36	320	0.001	0.004
940930	D	0.1354	0.4832	0.4126	166.5	11	38	7.8	19.5	9.2	162.7	0.708	21.36	290	0.002	0.008
941026	M	0.1839	0.3927	0.4494	213.5	24	33	8.3	13.5	9.7	126.72	0.408	21.36		0.001	0.001
941026	D	0.2017	0.3844	0.4386	200	20	36	8.2	14.5	8	125.8	0.625	14.24	290	0.001	0.001
941122	M	0.1739	0.4459	0.4079	216	26	36	8.6	7.5	9.5	116.16	1.36	10.68	300	0	0.003
941122	D	0.1841	0.4504	0.3926	210	25	43	8.4	8.5	9.8	120	1.3	5.34	280	0	0.001
941220	M	0.1735	0.5114	0.3467	162.5	100	62	8.4	2.9	11.9	108.48		12.46	390	0.007	0.005
941220	D	0.1389	0.4797	0.4115	178	92	83	8.4	2.5	12	107.5		13.35	255	0.002	0.006